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GLOBAL SNOW DEPTH CLIMATOLOGY

by

Dudley J. Foster, Jr.
and
Robert D. Davy

OL-A, USAFETAC
Asheville, North Carolina

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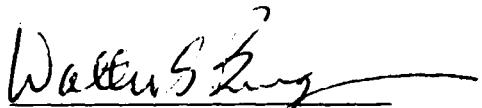
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PATRICK J. BREITLING
Chief Scientist

FOR THE COMMANDER



WALTER S. BURGMANN
Scientific and Technical Information
Program Manager

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PREFACE

In August 1985, The Air Force Global Weather Central (AFGWC) tasked the USAF Environmental Technical Applications Center (USAFETAC) with creating and maintaining a global snow depth climatology that could be updated as new data sources became available. USAFETAC passed that tasking to its Operating Location A (OL-A) at Asheville, North Carolina, where the present database was created and where it now resides. Certain data from that database have been converted to hand-plotted charts that portray global snow depth climatology; those charts are presented in the Appendix.

Before creating the climatological snow depth database, OL-A searched the literature for existing snow depth data and turned up only two useful references. The first was produced by the U.S. Army Corps of Engineers in 1954. It contained snow depth analyses for the eastern United States, Europe, and Russia, but much of Asia, the Arctic, Canada, and Greenland were omitted for lack of data.

The second basic reference found was a 1975 study by the Rand Corporation, which used data from the earlier Corps of Engineers product to give climatological snow depths on a grid measuring four degrees of latitude by five degrees of longitude. Rand added previously

missing information for China and Greenland, as well as for the Arctic and Antarctic.

In addition to the basic information provided by these two studies, OL-A's new snow depth climatology incorporates large amounts of recorded snow depth data from many other sources. In areas for which there was little or no data, OL-A devised ways to compute mean snow depths. Considering the large amount of data used, the methodologies developed, and the grid spacing of approximately 25 nautical miles, this work is, to our knowledge, the most complete global snow depth climatology, with the highest resolution, currently available anywhere.

Special recognition is due William R. Schaub, Jr., formerly of OL-A, who did extensive work on snow depths for Antarctica. Thanks also to Dr. David A. Robinson, Department of Geography, Rutgers University, for reviewing the climatology and providing additional guidance for determining snow depths in areas for which there is little or no recorded data. Finally, thanks to the Air Weather Service Technical Library at Scott AFB, Illinois, and the National Climatic Data Center Library at Asheville, North Carolina, for their assistance in performing an extensive literature search.

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Chapter 1

INTRODUCTION

THE AFGWC SNOW ANALYSIS MODEL (SNODEP). The Air Force Global Weather Central (AFGWC) at Offutt AFB, Nebraska, runs its Snow Analysis Model (SNODEP) once a day to produce daily global snow age and depth analyses. As input, the model uses current weather observations (surface synoptic reports), the snow climatology discussed in this study, time continuity, and manual updates. Output from the model is sent daily to OL-A, USAFETAC, where it is entered in the Snow Depth Analysis Dataset. The snow depth model, its output, and output applications are described in detail by AFGWC/TN-86/001, AFGWC Snow Analysis Model, February 1986.

HISTORY OF THE SNOW DEPTH CLIMATIC DATABASE. The original snow and ice climatology input for the SNODEP model was developed in 1974. It was limited, and drew from only three main

sources: a 1954 U.S. Army Corps of Engineers snow depth study, a 1951 Arctic snow depth study by Pettersen, and snow depth data from state water resource snow courses. Although there have been changes made to the original climatology since 1974, none, up to now, have been documented. Because the original data sources were so limited, and because there were so many undocumented changes over time, there was predictable deterioration in the accuracy and continuity of snow depth data. In 1985, therefore, AFGWC decided that a new snow and ice climatology was needed--one that: (1) incorporated current data sources, (2) was fully documented, and (3) was capable of being easily updated as new data sources and methodologies became available. OL-A, USAFETAC, was tasked to create an entirely new snow depth climatic database to suit those needs and now maintains that database in Asheville, NC.

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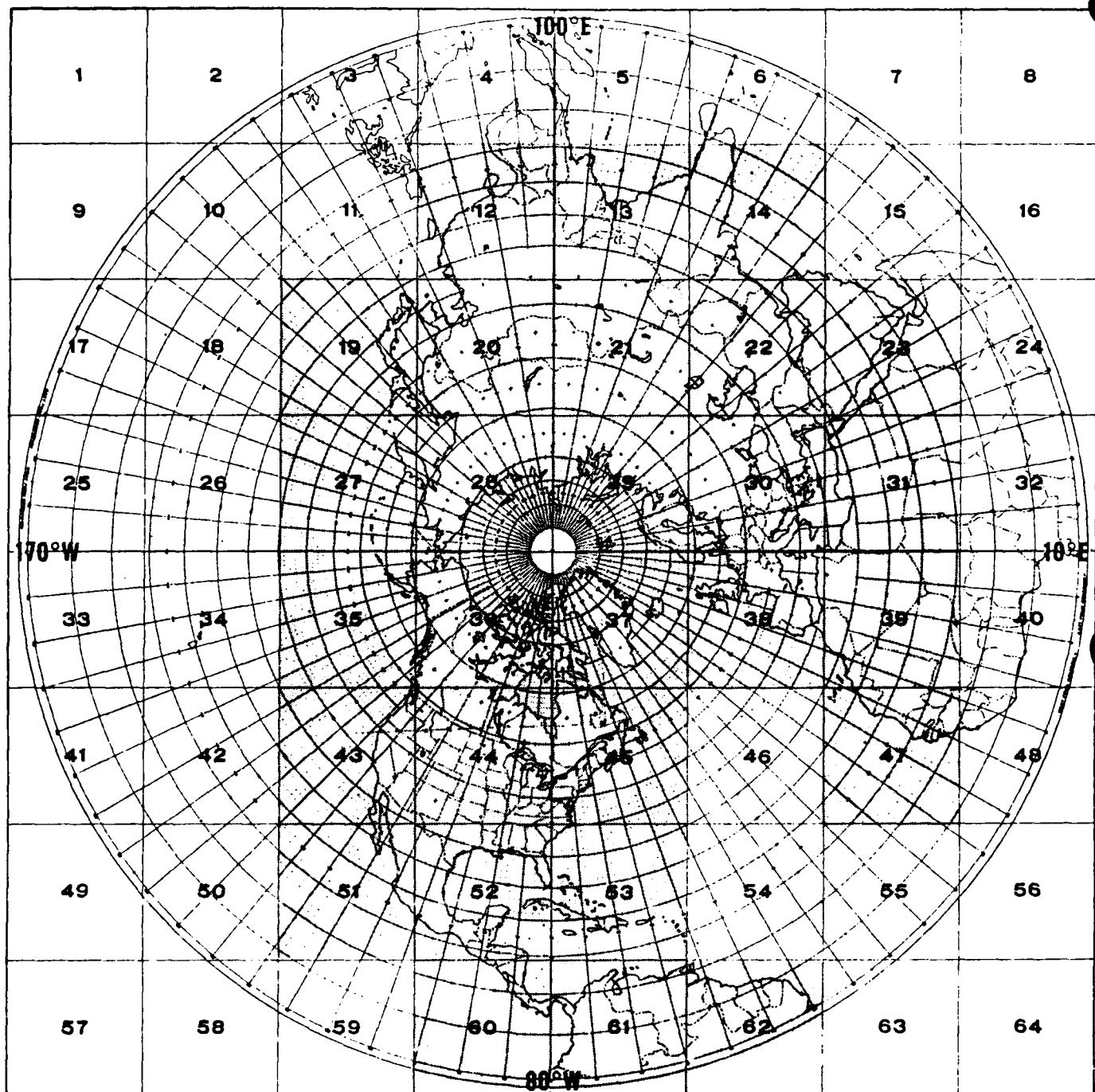
Chapter 2

DESCRIPTION OF THE SNOW DEPTH CLIMATIC DATABASE

SNODEP REFERENCE GRID. SNODEP climatology uses the standard eighth mesh reference grid (See Figures 1 and 2). This grid divides each hemisphere into 64 equal boxes. Each box is divided into 4,096 grid points that are about 25 nautical miles apart. Each grid point within a box (numbered from 1 to 64) is identified by an "I" (horizontal) and a "J" (vertical) axis. Any grid point on the globe can be located by its grid box and its "I" and "J" coordinates. For every month, every box, and every grid point, a snow depth value (mid-month snow depth to the nearest whole inch) is assigned. For more information on the

eighth mesh grid, see AFGWC/TN-79/003, *Map Projections and Grid Systems for Meteorological Projections*, March 1981.

UPDATE CAPABILITY. As previously described, the newest snow depth climatology was developed with a capability to be easily updated; if OL-A receives information that would improve the climatology significantly, that information can easily be added to the database. The bibliography provides a list of data sources used to create the database, along with an indication of confidence in the quality of those sources.



NORTHERN HEMISPHERE

Figure 1. Northern Hemisphere Eighth Mesh Grid. A snow analysis is generated for the shaded grid boxes.

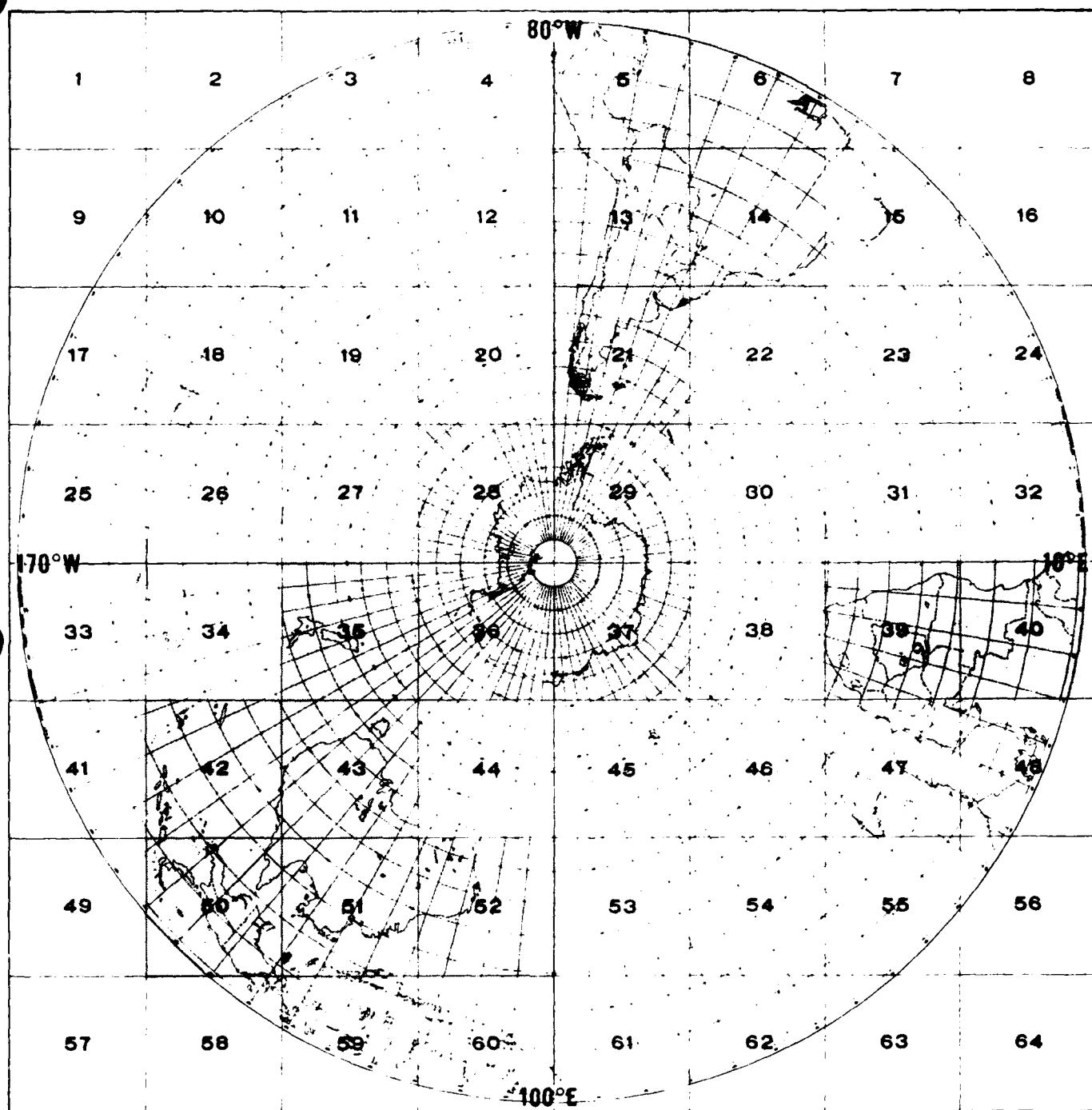


Figure 2. Southern Hemisphere Eighth Mesh Grid. A snow analysis is generated for the shaded grid boxes.

Chapter 3

HOW THE SNOW DEPTH CLIMATOLOGY WAS PRODUCED

LITERATURE SEARCH. The first step was to initiate an extensive literature search. Snow depth information was obtained from the Air Weather Service Technical Library at Scott AFB, Illinois; from the 2nd Weather Wing at Kapaun Air Station, Germany; from the National Climatic Data Center Library at Asheville, North Carolina; from the World Meteorological Organization (WMO) at Silver Spring, Maryland; from the Cold Regions Research Engineering Laboratory Library at Hanover, New Hampshire; and from the World Data Center A for Glaciology at Boulder, Colorado. Other data came from the U.S. Forest Service at Fort Collins, Colorado, and from the U.S. Department of Agriculture's Soil Conservation Service at Portland, Oregon. Specific documents and data used to build the database are listed in the bibliography, along with a "confidence factor" for each source.

BUILDING THE DATABASE. At OL-A, data from the numerous sources mentioned was plotted on hemispheric maps, month by month. The maps were then hand analyzed. An acetate transparency of an eighth mesh grid box with 4,096 points was then placed on the analyzed maps; snow depth values were read at each grid point and digitized into files. Each grid value was compared from month to month to insure temporal consistency of the data. The process was repeated until every box in both hemispheres was complete.

QUALITY CONTROL. A computer program was used to print out entire eighth mesh boxes from the digitized data. The printouts were thoroughly quality controlled against the original analysis to insure that data had been entered correctly.

DATA-SPARSE AREA METHODOLOGIES.

Although the extensive literature search resulted in the acquisition of large amounts of global snow depth reference materials, there were still areas of the world for which snow depth reference material could not be located. Certain methodologies, therefore, were developed to provide mean snow depths for these data-sparse areas.

Antarctica. In 1971, Bull calculated annual snow accumulation in g/cm² of water equivalent for the Antarctic continent. By dividing mean annual water equivalent by snow density, it is possible to calculate snow depth:

$$\text{Mean Annual Water Equivalent (g/cm}^2\text{)} \\ \text{Depth (cm)} = \text{-----} \\ \text{Density (g/cm}^3\text{)}$$

The literature search produced a number of references to Antarctic snow densities. Observations at Plateau Station by Koerner (1971), for example, indicated that densities in the high plateau were 0.3 g/cm³. At Little America and McMurdo (on the immediate coast of the Ross Ice Shelf), Heap and Rundle (1964) also calculated snow densities to be 0.3 g/cm³. Densities of 0.4 g/cm³ were calculated at Dome C by Petit, et al (1982), at Byrd by Koerner (1964), southwest of the pole in the lower terrain by Taylor (1971), and at Wilkes Station by Cameron (1964).

With densities established, the next step in obtaining actual values for mean annual snow depth was to divide mean annual water equivalent by an area's density. But before apportioning the mean annual snow depth into mean monthly values, it was necessary to

consider how much of the annual accumulation was attributable to liquid precipitation. Although most Antarctic precipitation is frozen, conditions along the coasts and peninsula allow the possibility of liquid precipitation during warmer summer months. To determine the months in which liquid precipitation occurred, daily temperature ranges for stations provided by Schwerdtfeger (1970) were used. Based on this data, mean annual snow depth values were subjectively reduced along the coast by 15 percent, along the northern half of the peninsula by 30 percent, and along the southern peninsula by 50 percent.

Climatological cyclone tracks that affect Antarctica change little throughout the year. This consistency (shown in seasonal maps by Rusin, 1961) allowed OL-A to use the same contour pattern for all months. The only places that saw variation were around the periphery of the continent where ice pack coverage changes from month to month.

The final step in computing Antarctic snow depth was to relate mean annual precipitation to mean monthly precipitation and apply the results to annual mean snow depth. Stations with the best periods of record for precipitation were grouped according to location so as to relate mean annual to mean monthly precipitation. After calculating the percent of precipitation occurring each month, overall means were determined by averaging the percentages for all the stations. These results were applied to the mean annual snow depth field values for partitioning into mean monthly depths. A bimodal snow depth distribution was evident; there was an increase in autumn and spring, and a decrease in summer and winter due to melting, evaporation, and sublimation.

Greenland and the Arctic. OL-A used data from a snow depth study by Schutz and Bregman (1975) of the Rand Corporation. For Greenland, the Rand Corporation had used basically the same methodology as has already

been discussed for Antarctica. Bader (1961) had already calculated the yearly water equivalent for Greenland. The Rand Corporation then calculated snow density to be 0.3 g/cm³, using values from Bilello (1961). Rand developed curves based on the accumulated percentages of annual precipitation to compute the monthly distribution of the annual snow depth. Coastal snow depth was provided by Petterssen, et al (1956). Rand found annual precipitation for the Arctic meager; average yearly water equivalent was under 12 inches, keeping snow depth in most places at less than a foot. Precipitation was mainly in the form of snow, with maximums in autumn and late spring, and minimums in winter. May was the month of maximum accumulation.

China. OL-A obtained five Chinese journals (1975-1979) from the National Climatic Data Center (NCDC). These journals contained maximum monthly snow depths for 200 Chinese stations. After summarizing this data, a subjective value of 80 percent of the total depth was used to estimate the mean. A World Meteorological Organization (WMO) Climatic Atlas (1981) was used to determine which stations were cold enough to sustain a monthly snow depth; those stations north of the monthly 0 to -5°C median temperature lines were plotted.

Mountainous Areas. Almost all mountainous regions are data void. The methodology used for computing mean snow depths in the mountains was similar to that used in other data-void areas; that is, by using water equivalent and snow density to calculate snow depth. A value of 0.3 g/cm³ was used as the snow density. WMO's Climatic Atlases (1981 & 1970) were used to obtain mean monthly precipitation; it was assumed that all precipitation in the mountains was snow. Other sources were useful for indicating which mountain ranges received snowfall and when snow cover starts and ends, and for approximating average winter snow depths.

Ice-Covered Areas. The Navy's Sea Ice Climatic Atlases were an excellent source for determining ice edges. Mean ice coverage of

five tenths was used to establish the ice edge. In most cases, snow depths were gradually and linearly reduced to zero at the ice edges.

Chapter 4

CLIMATIC DATABASE CONSTRUCTION AND FORMAT

DATABASE CONSTRUCTION. Snow depth climatic data is on ASCII, nine-track, 6250 BPI, 32-bit tapes, with a fixed record length of 16,408 bytes. There is one tape per hemisphere.

DATA ORDERING. Department of Defense (DoD) customers should submit requests IAW AWSR 105-18 or Department of the Army Pamphlet 115-1. Non-DOD customers submit requests to the National Climatic Data Center

(NCDC), Federal Building, Asheville, NC 28801-2723. Data is normally provided to customers on 6250 BPI magnetic tapes in the database format specified here.

DATABASE FORMAT. Snow depth climatic data is provided in two sections: "Control" and "Data." Those sections, and their fields, are shown below:

CONTROL SECTION											
Field	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	
!Data	RCD	!HEMI	SN	BOX	C	YEAR	MONTH	DAY	HOUR	BLK	
!Field	LNG										
# Char.	XXXXXX	XXXX	XX	XX	X	XX	XX	XX	XX	XXX	
!Location	1-5	6-8	9-10	11-12	13	14-15	16-17	18-19	20-21	22-24	

FIELD	DESCRIPTION	CODE
C01	Record Length	16408 Bytes
C02	Hemisphere	NH = Northern Hemisphere SH = Southern Hemisphere
C03	Snow ID	SN
C04	Box	01-64 (eighth mesh boxes)
C05	C	Climatology
C06	Year	Coded as 99
C07	Month	01-12 = Jan-Dec
C08	Day	Coded as 99
C09	Hour	Coded as 00
C10	Blank	3 ASCII Blanks

DATA SECTION		
	! data	! data ... ! data
	! for	! for ... ! for
!Data	! Grid	! Grid ... ! Grid Point
!Field	! Point1!Point2!...	4096
# Char.	XXXX	XXXX ... XXXX
!Location	25-28	29-32 ! 16405-16408

Data for grid points are in inches times 10 and are right justified and zero filled. Each box is contained on one record.

Example of a grid point: 0150 = 15 inches.

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High Confidence: Summarized snow depth values were available, and there were more than 5 years' period of record.

Fair Confidence: Summarized snow depth values were limited; discussion material was insufficient to produce a high degree of confidence.

Low Confidence: Summarized snow depth values were not available, and there was only limited discussion material.

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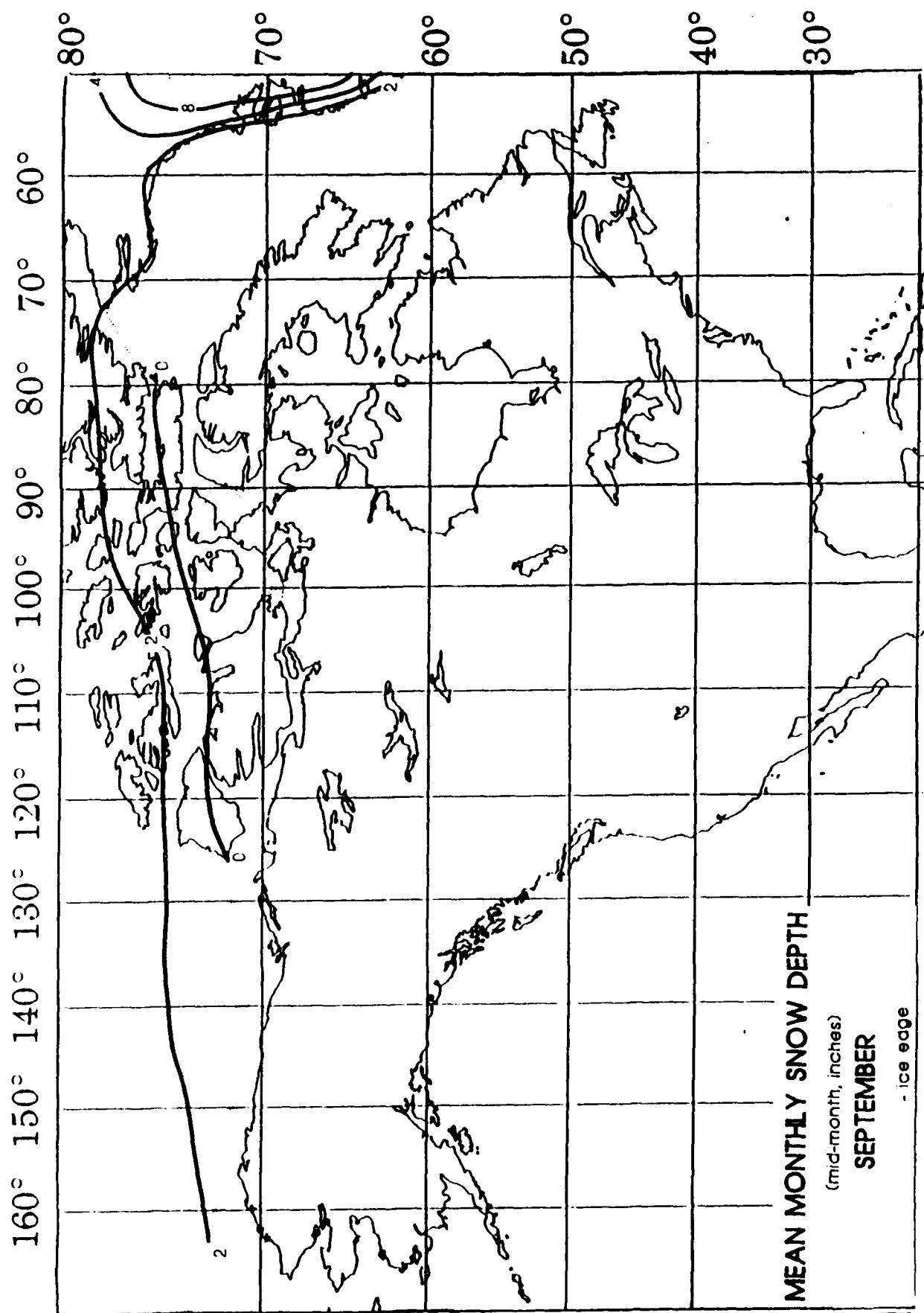
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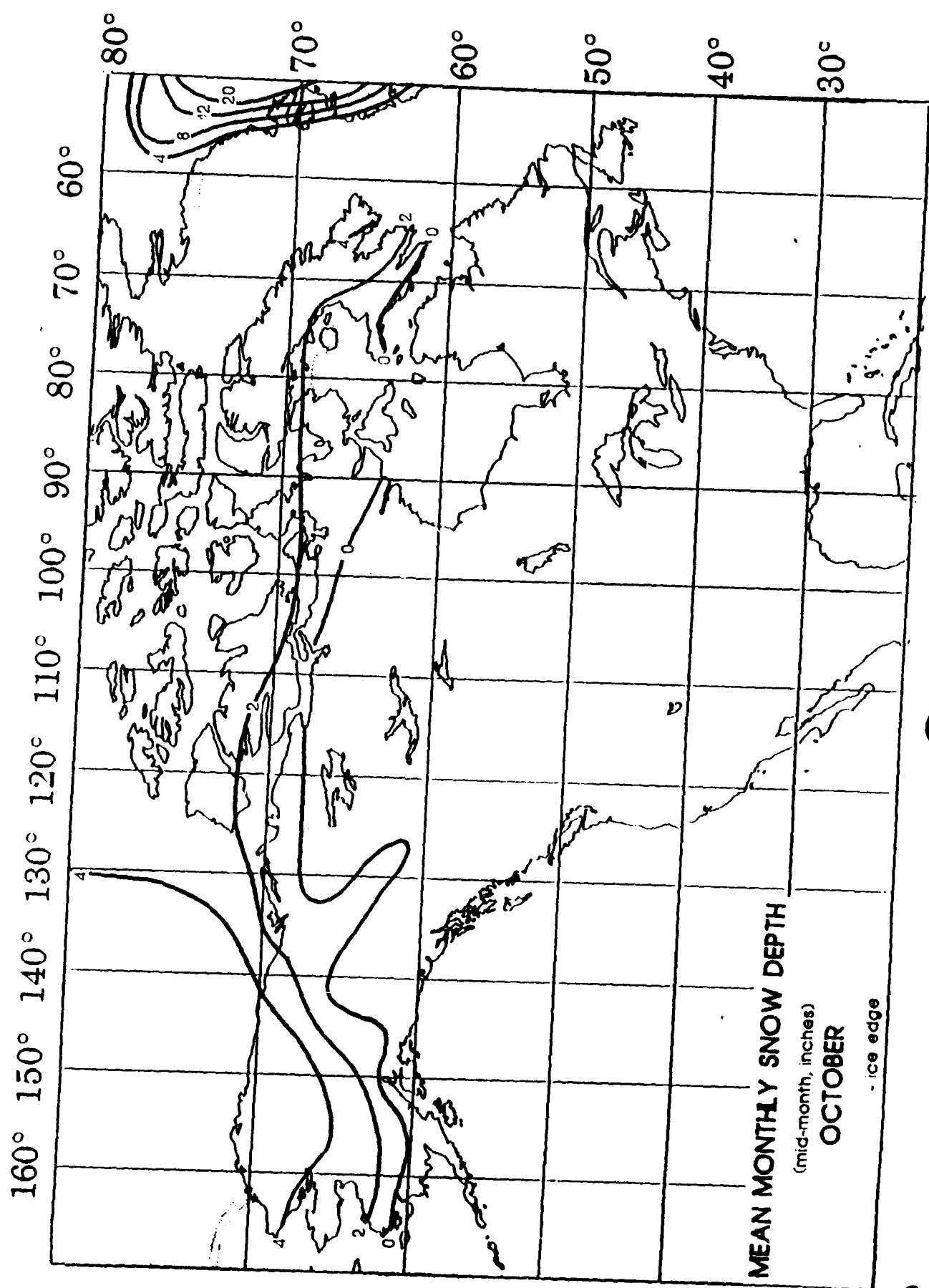
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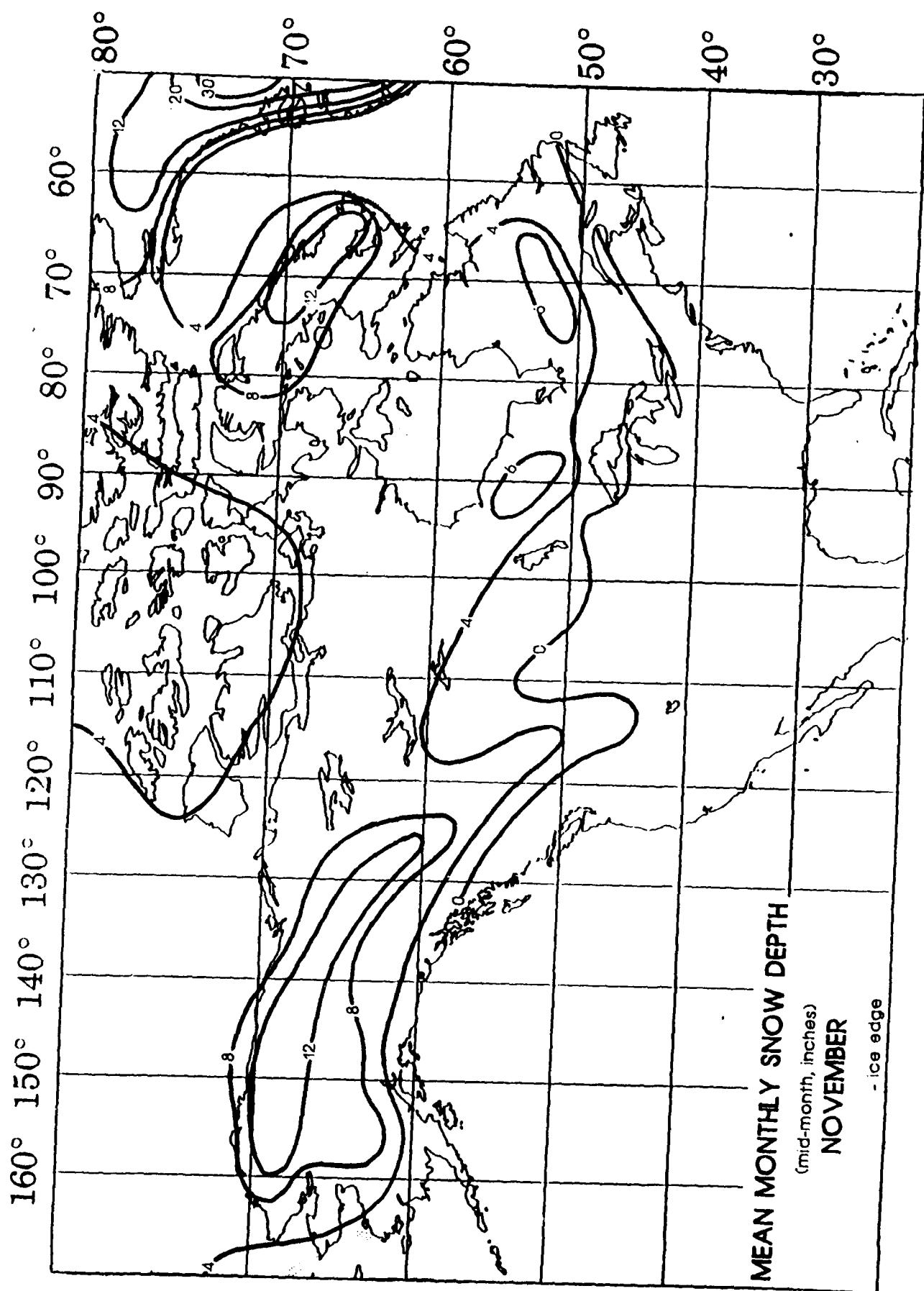
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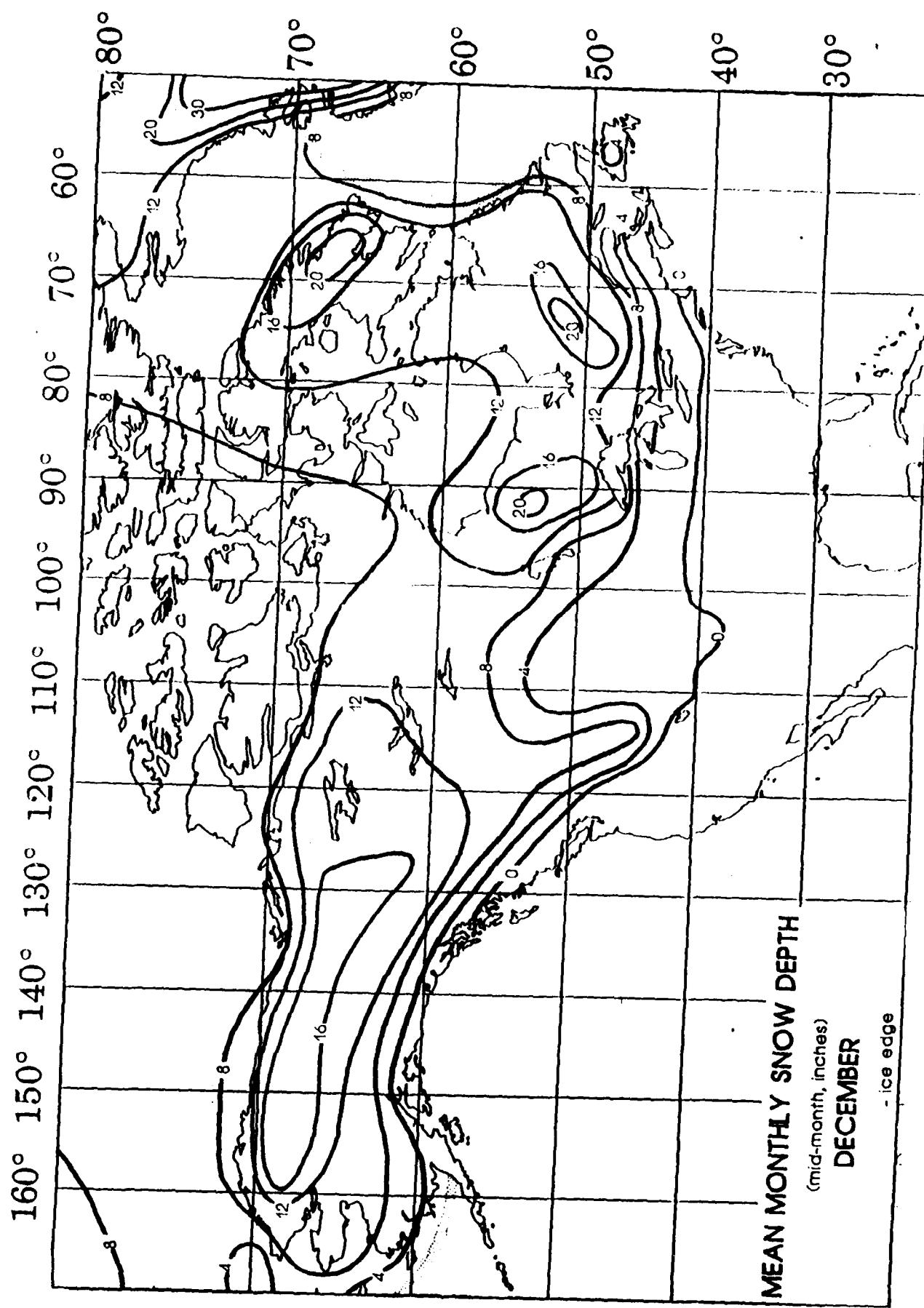
Global Snow Depth Charts

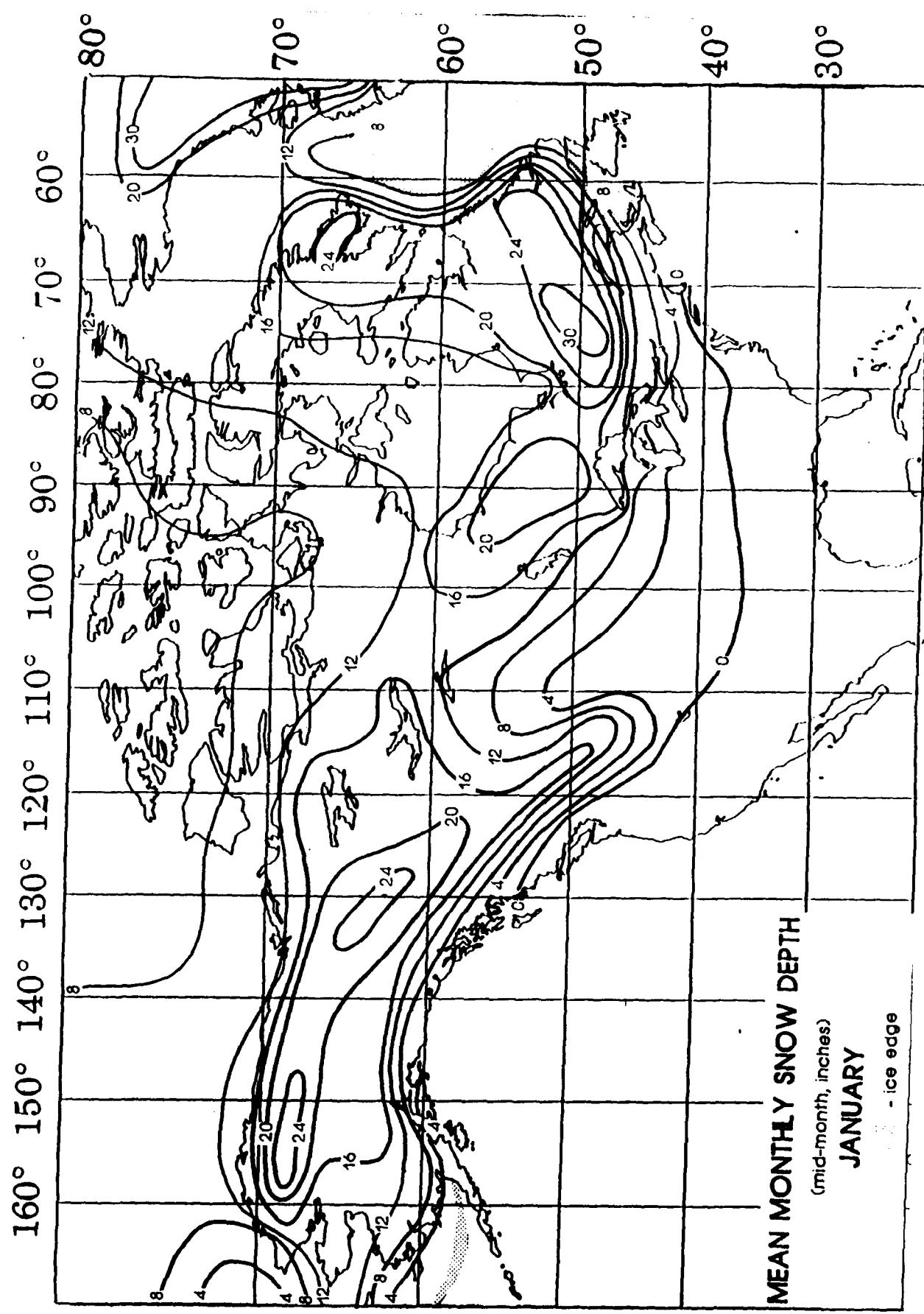
The contoured charts in this appendix show mid-month snow depths in inches for the months of September through June. The charts were analyzed from data plotted at every 5 degrees of latitude and longitude. If no zero line is present, assume the land mass boundary or the ice edge to be the zero line. Contours were drawn every 4 inches up to the 20-inch contour, and every 10 inches after that. Where spacing allowed, intermediate contours were drawn. Because of the resolution, Japan and the United Kingdom are not analyzed. Mountainous areas are smoothed throughout. The resolution of this chart series does not allow for true snow depths in Greenland, where they are much greater than indicated. Correct snow depths for all these areas, however, can be obtained from the data tape.

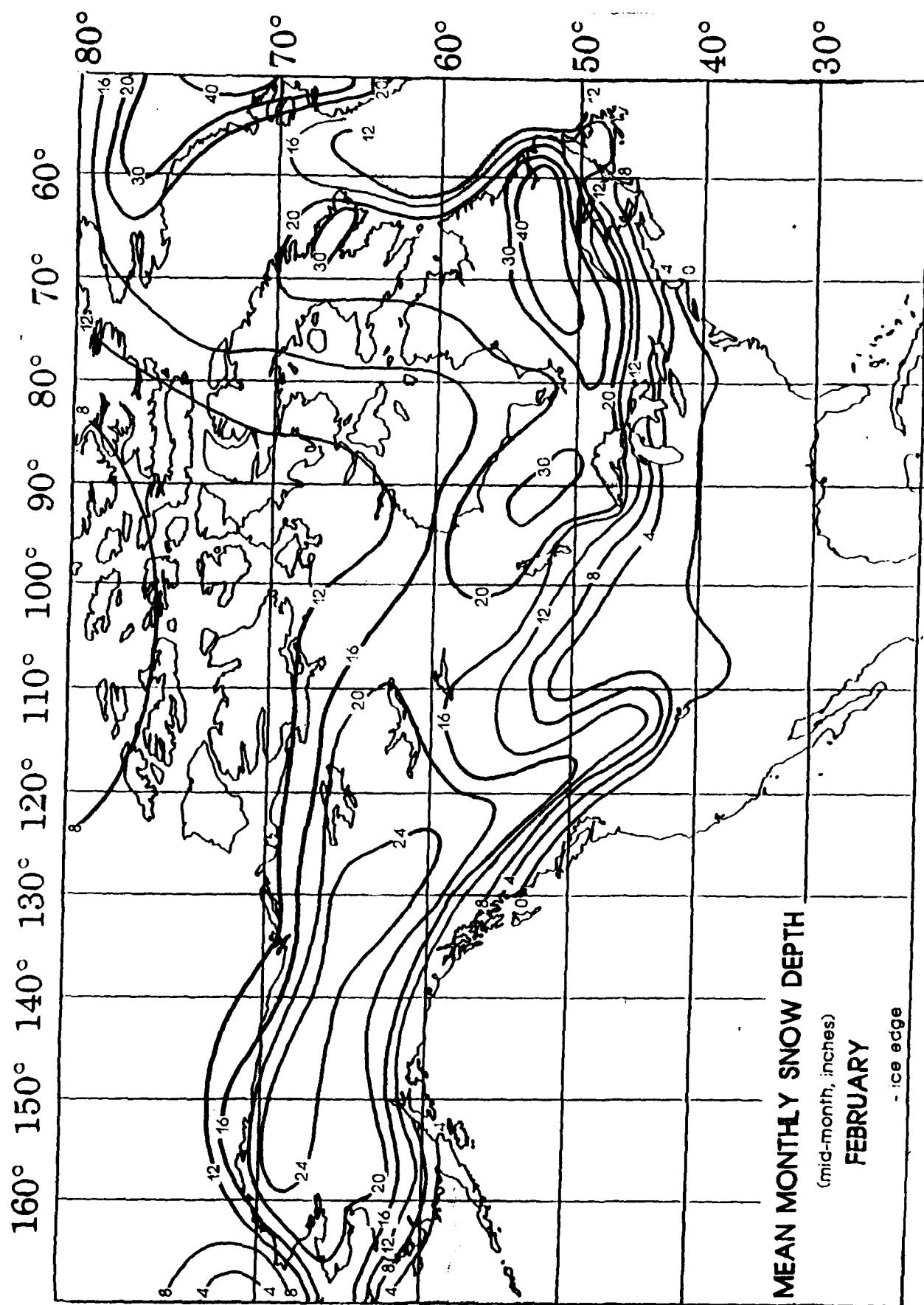


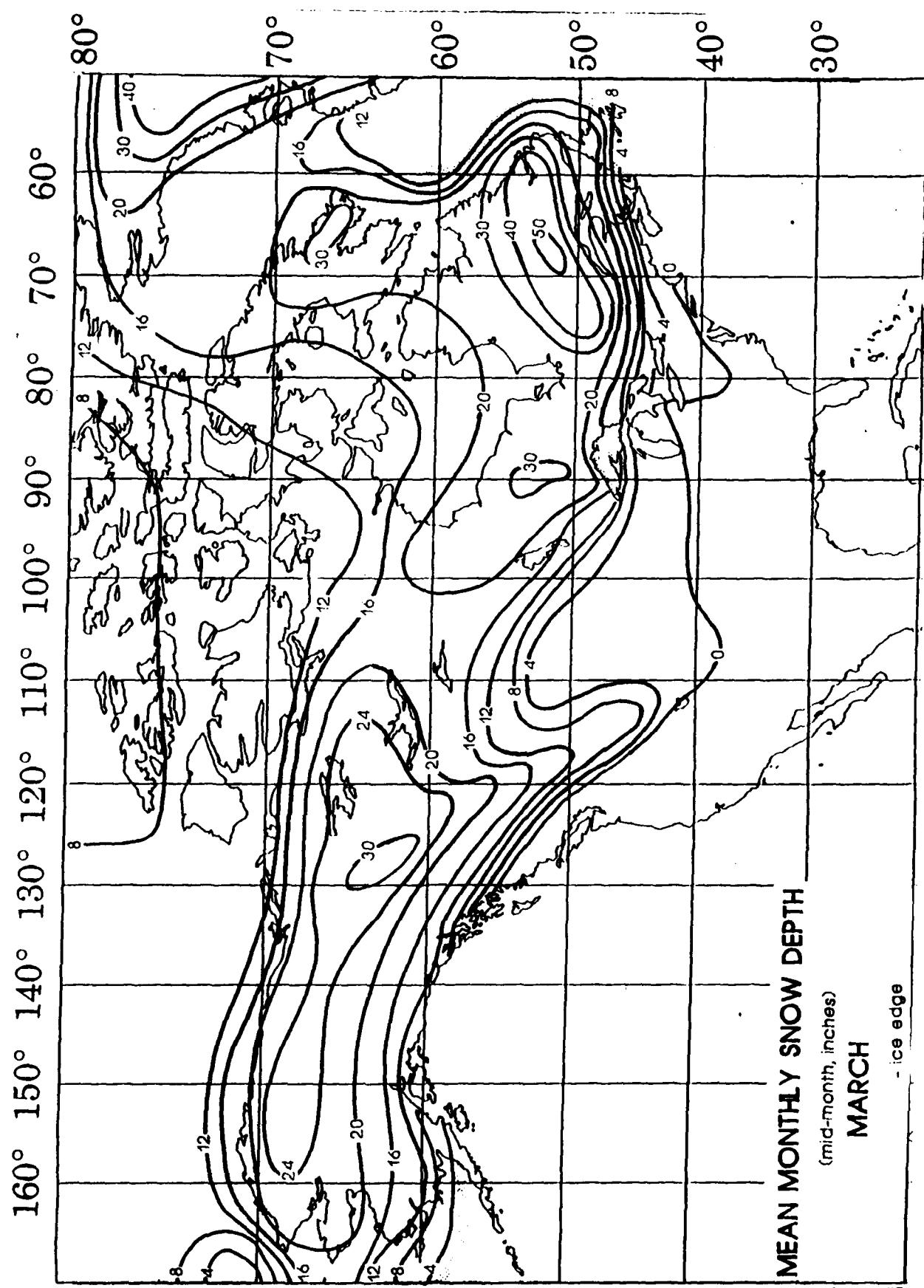


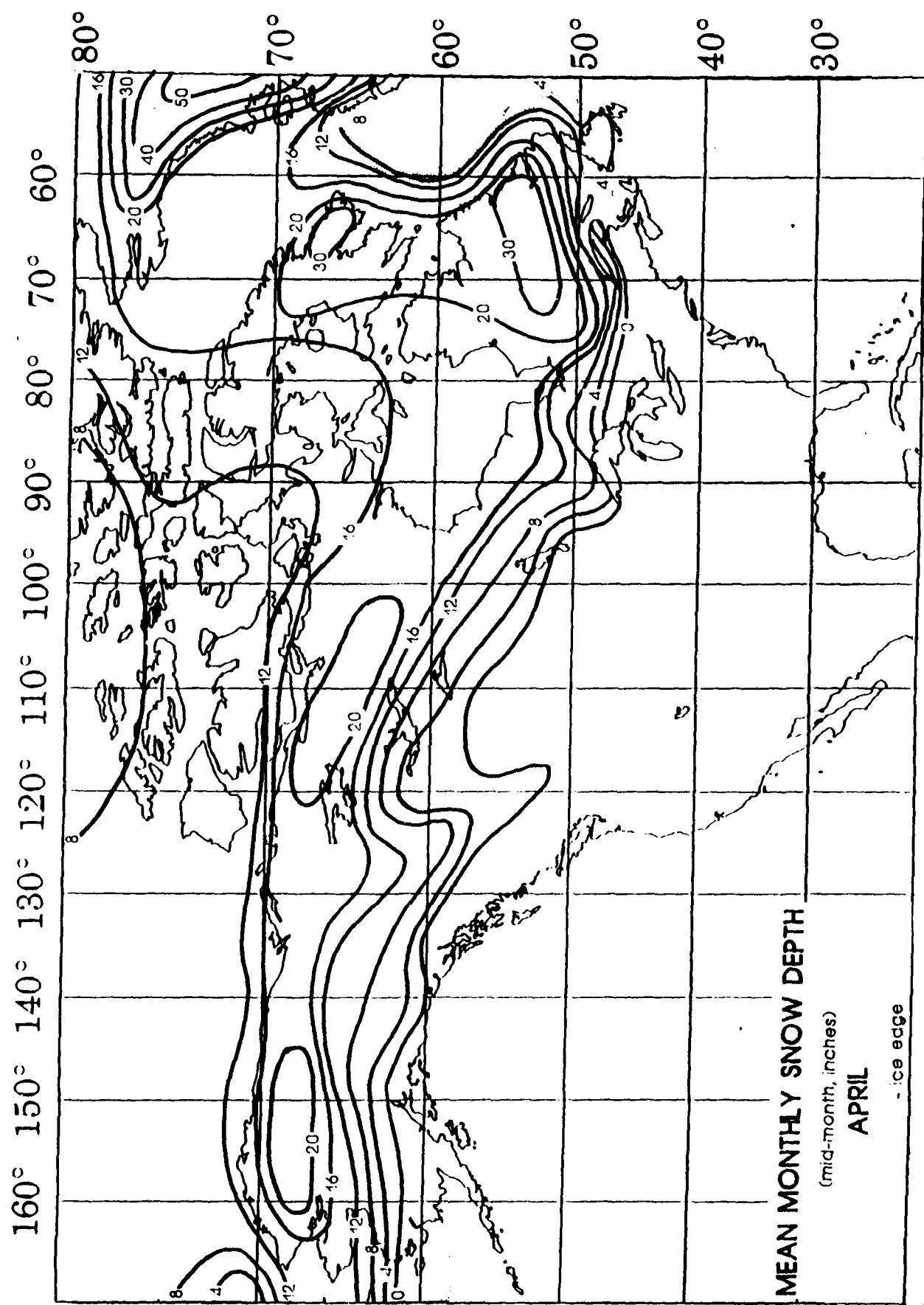


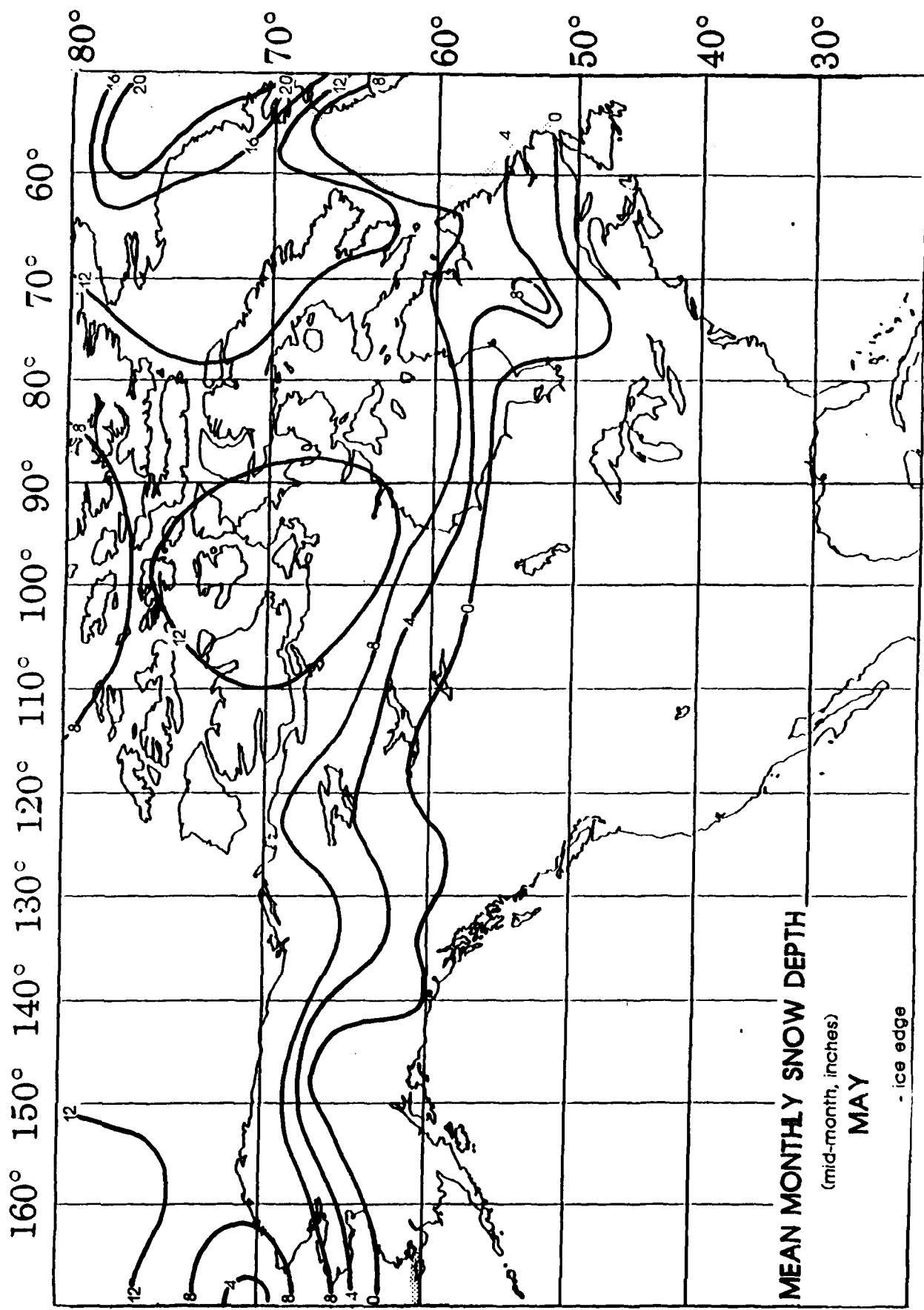


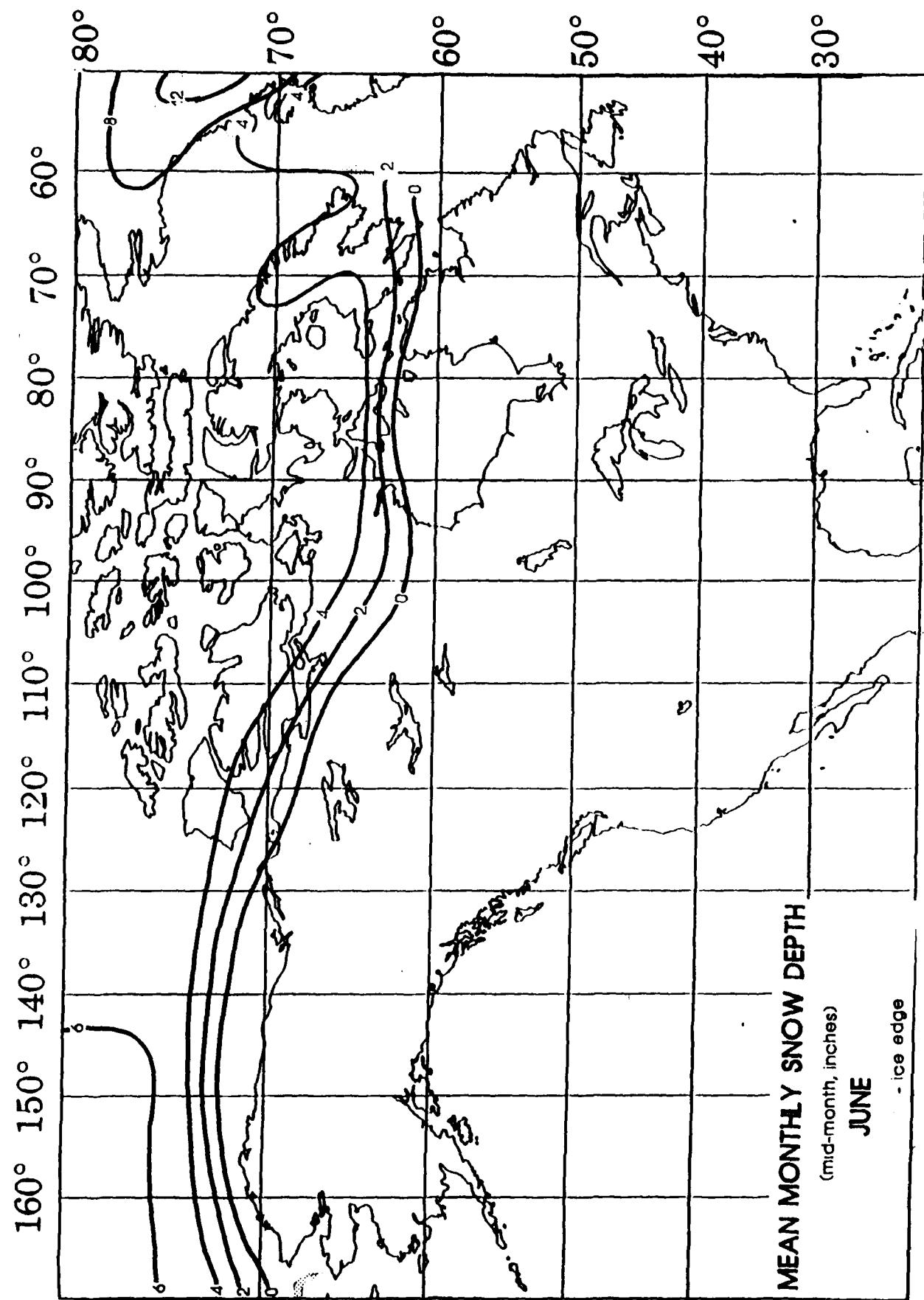


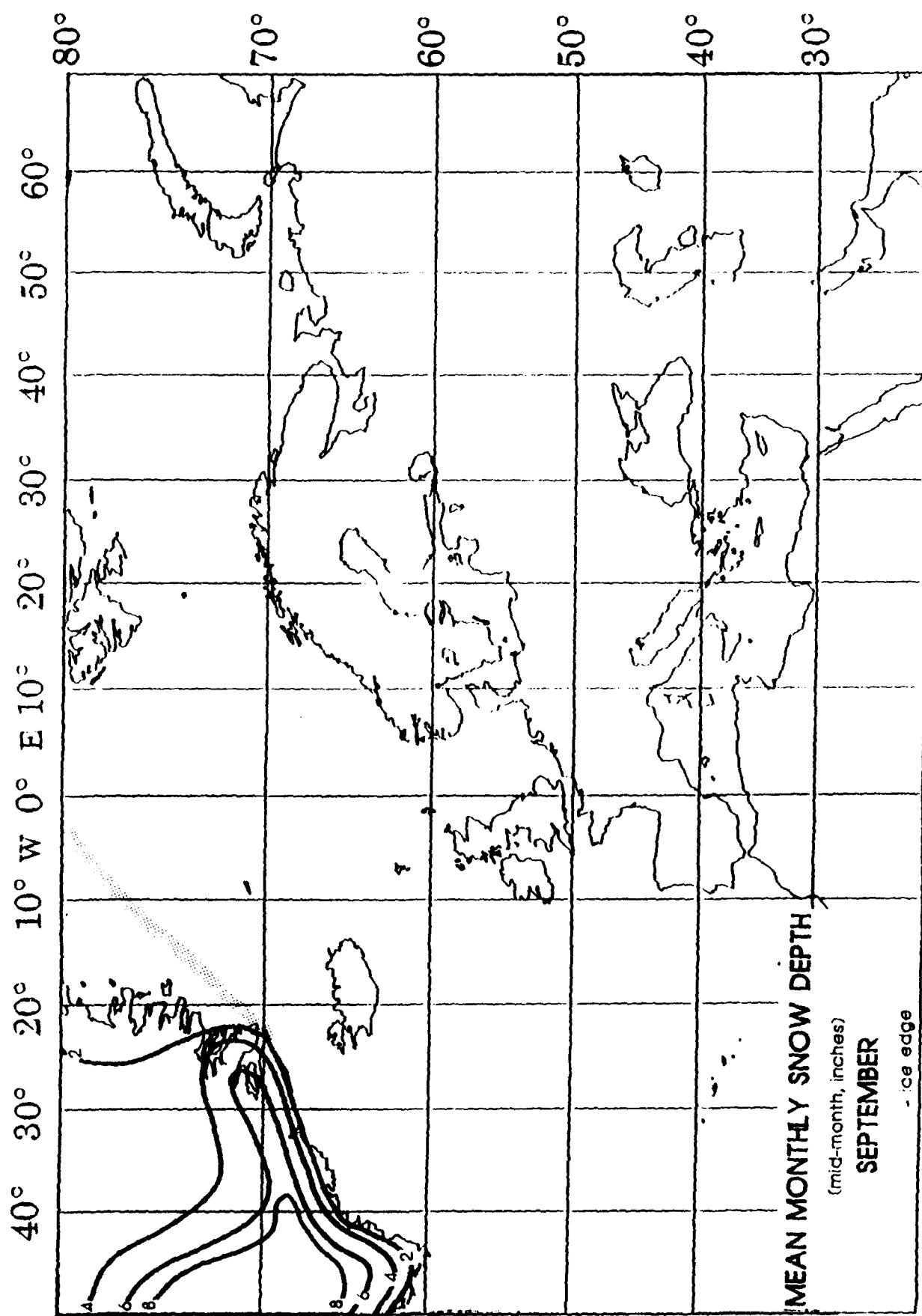


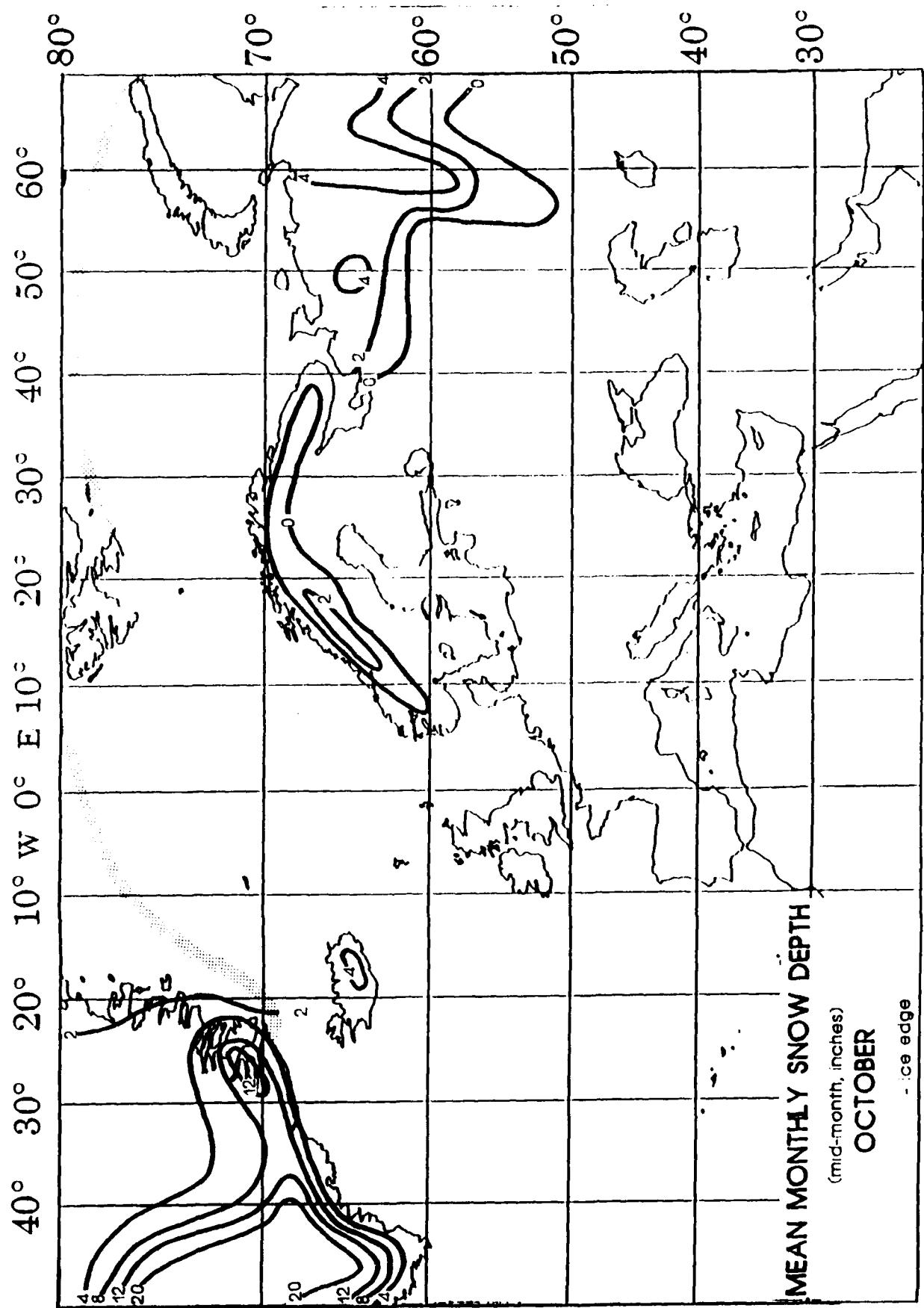


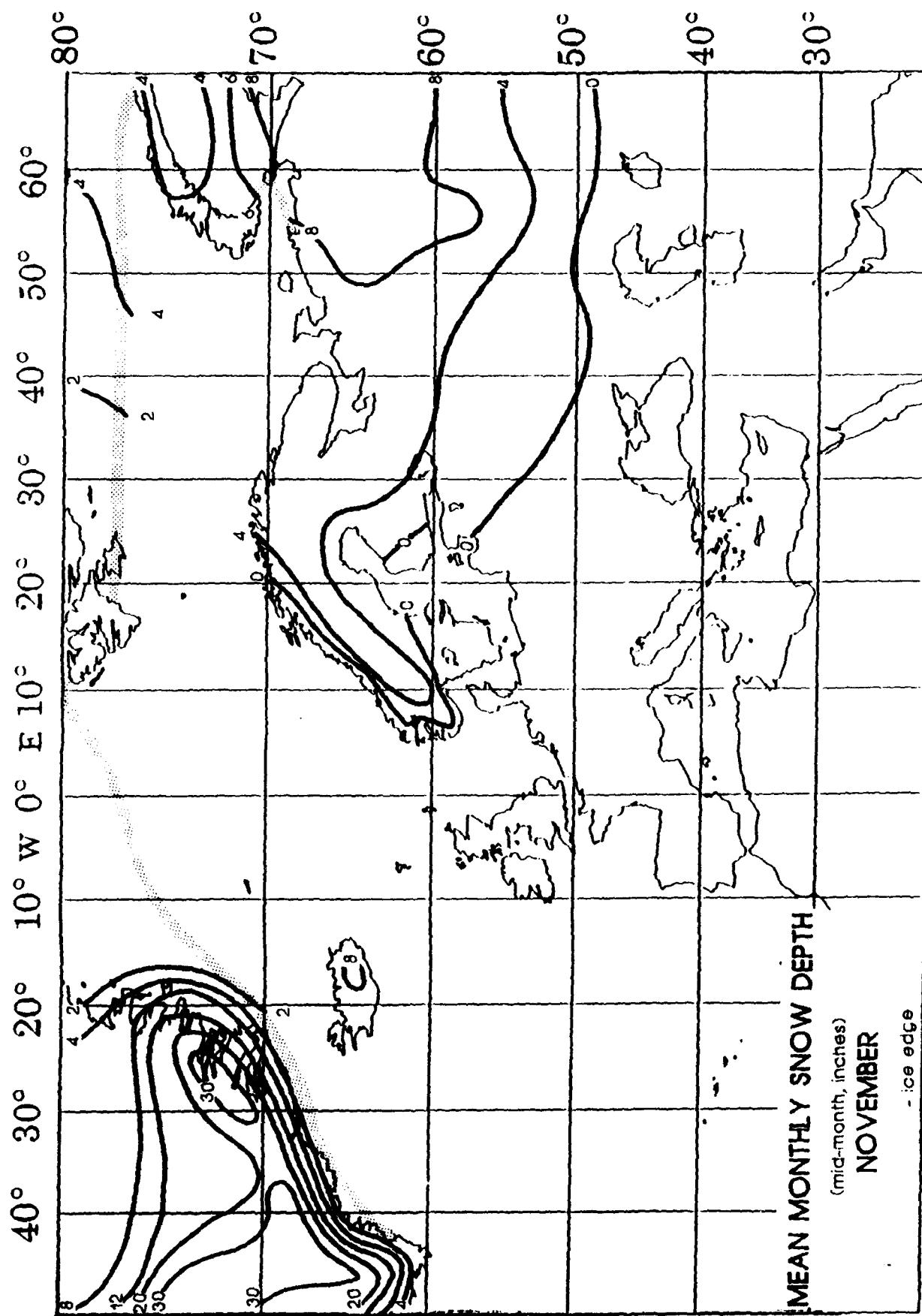


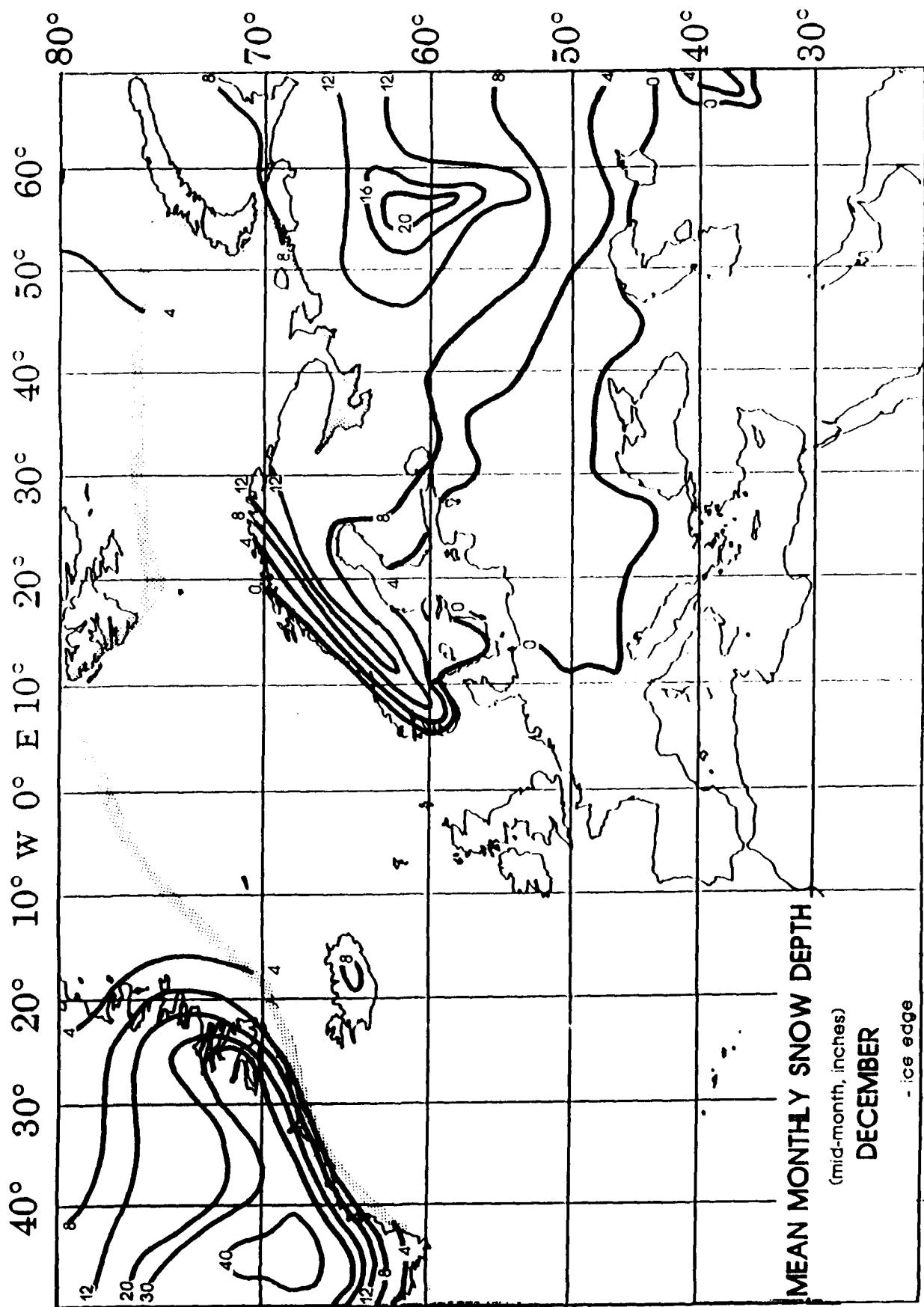


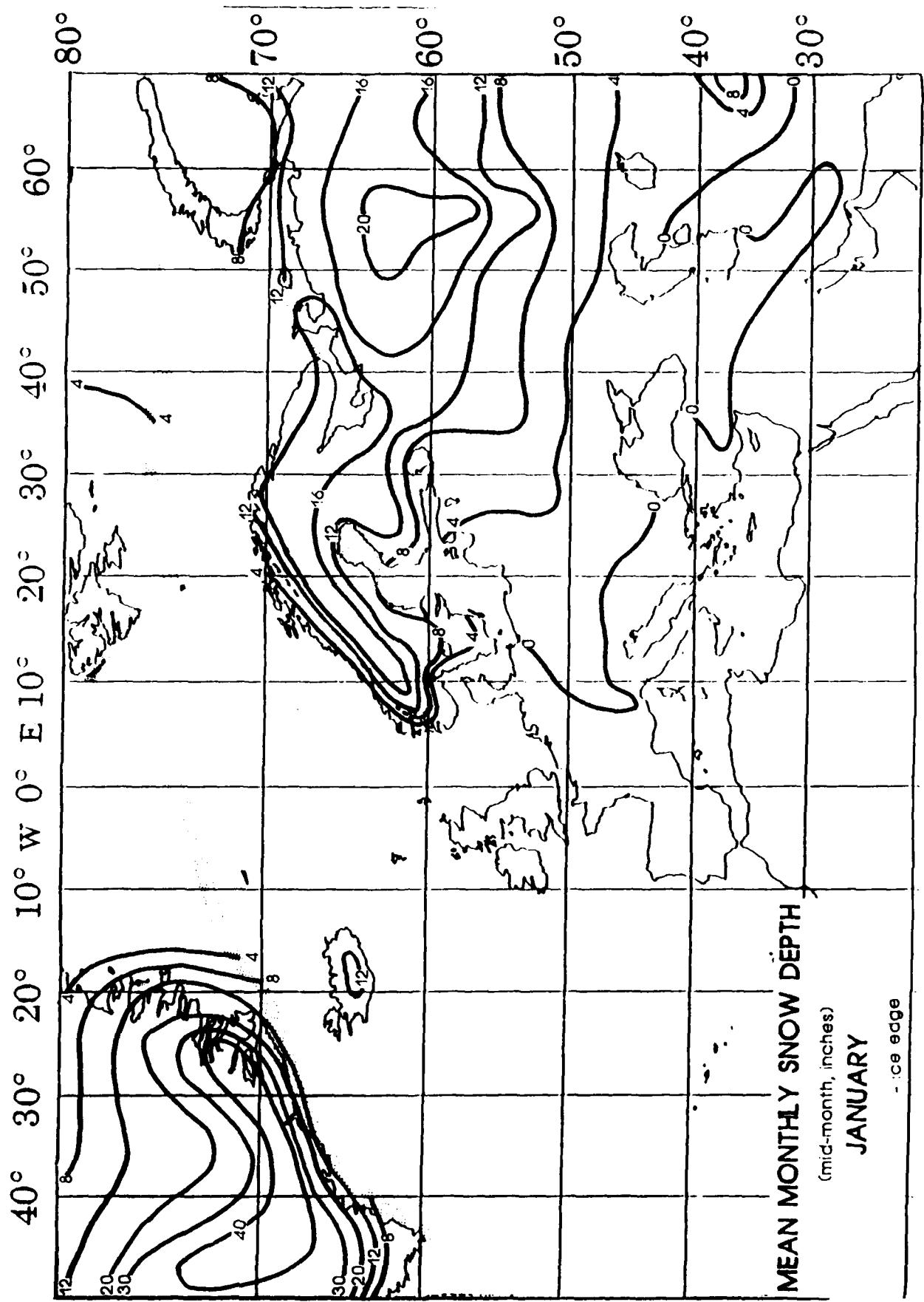


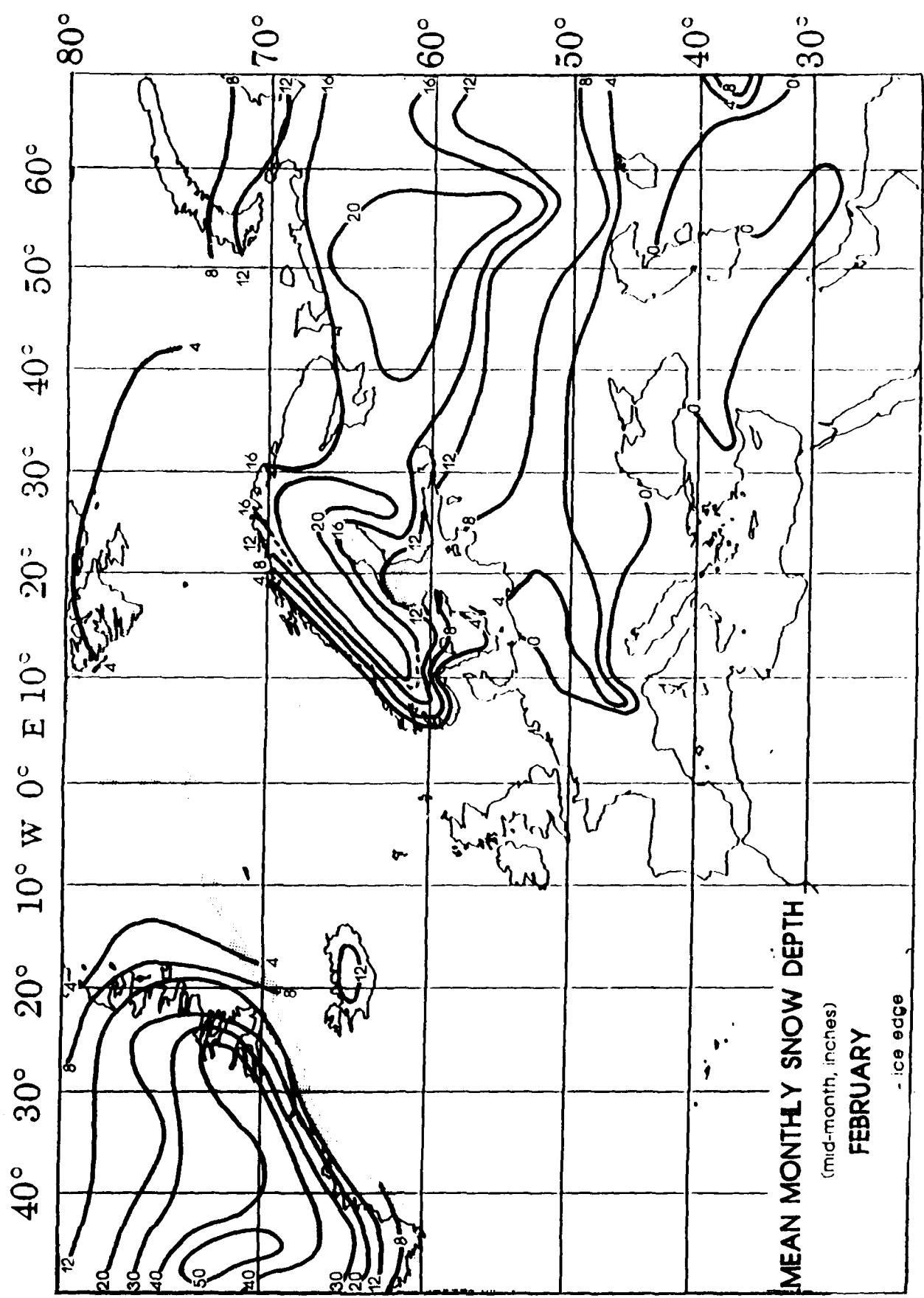


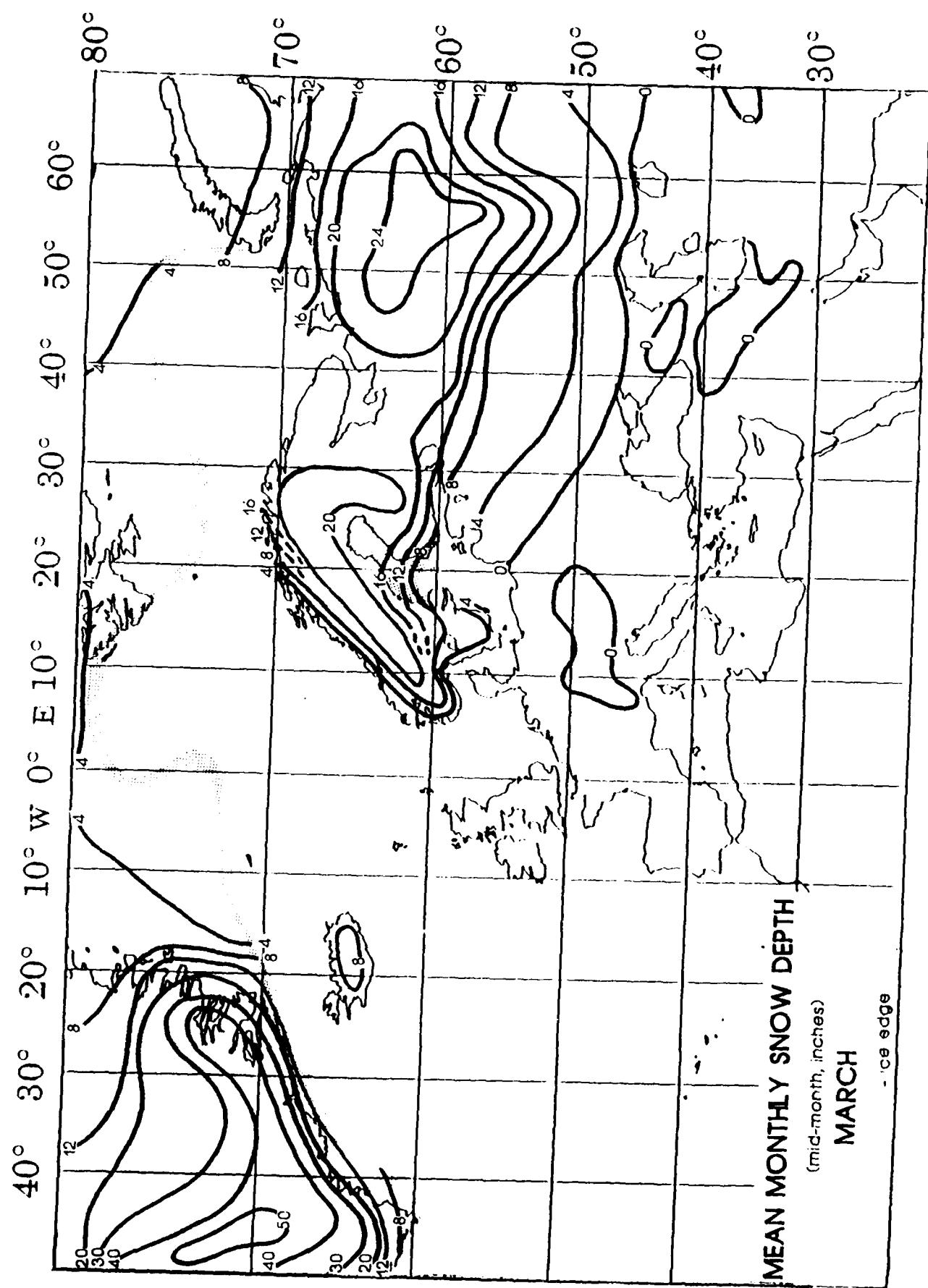


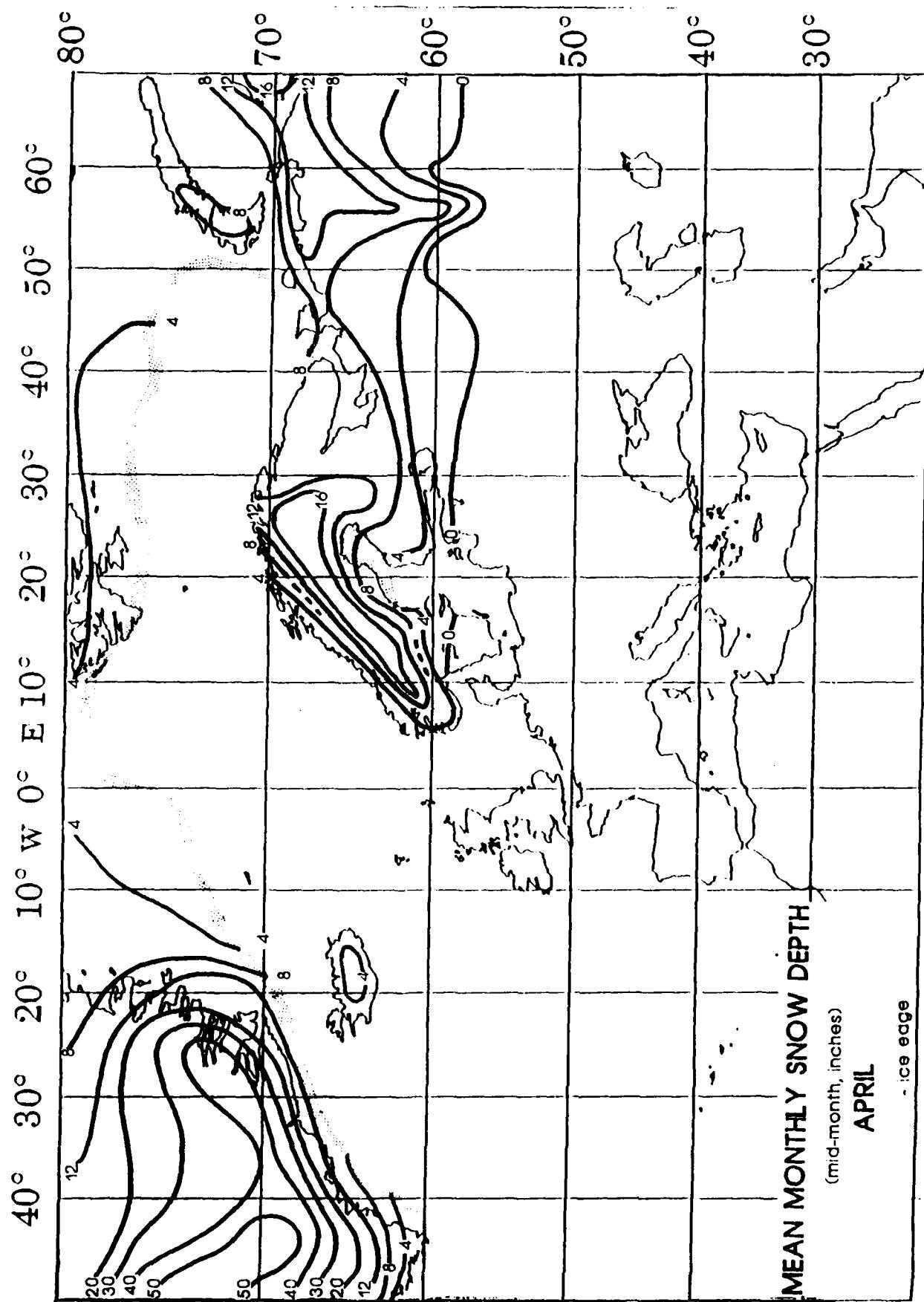


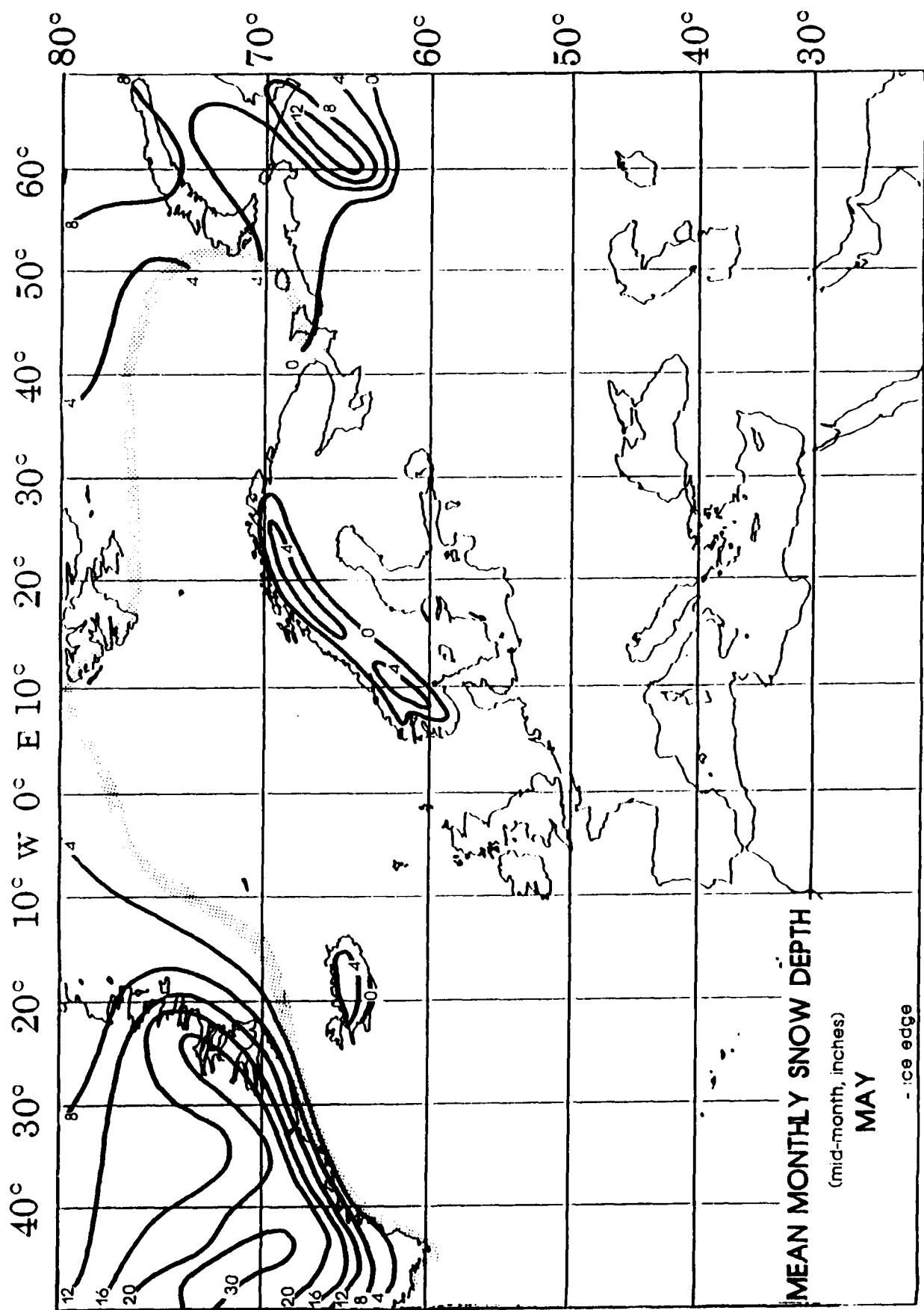


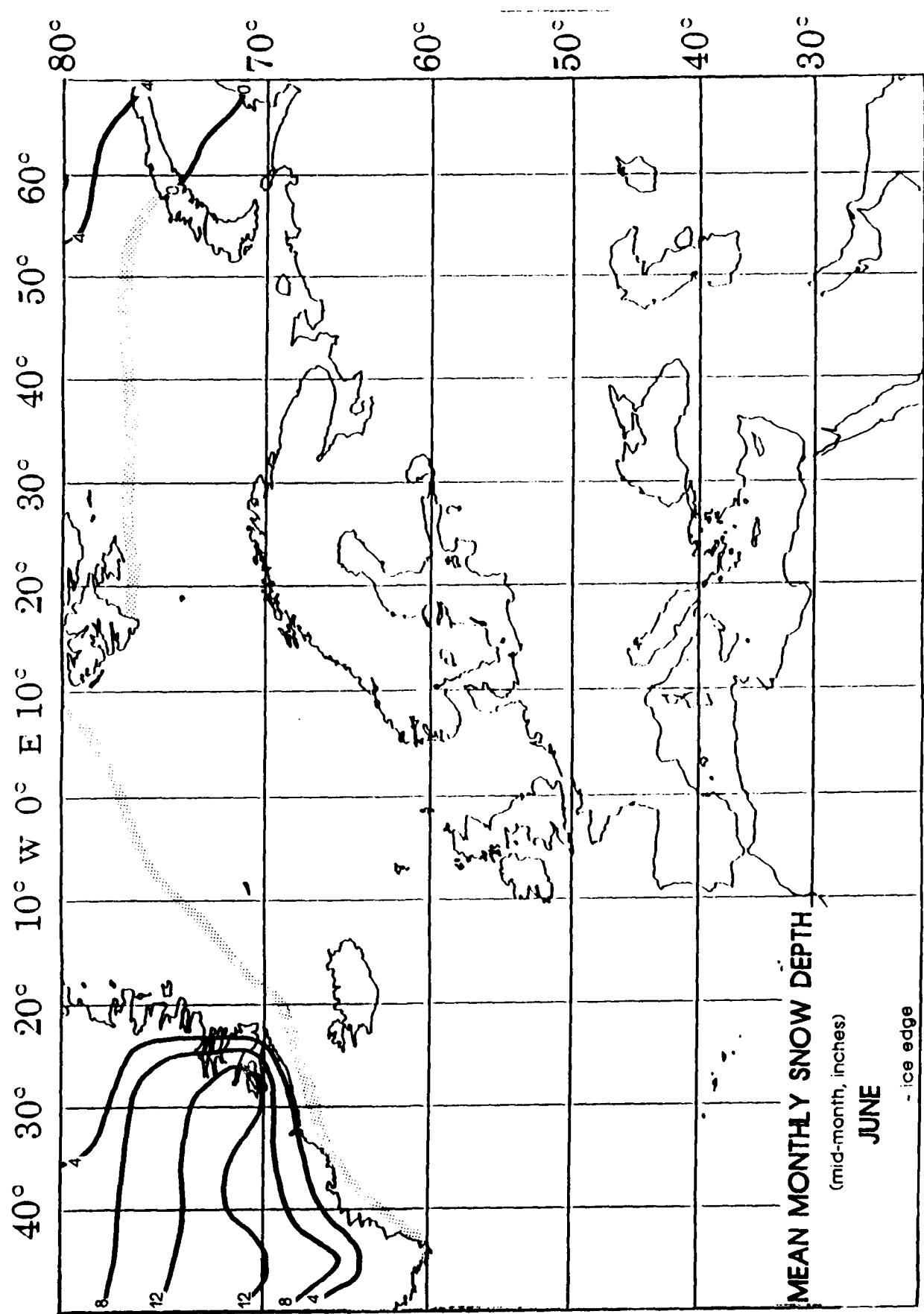


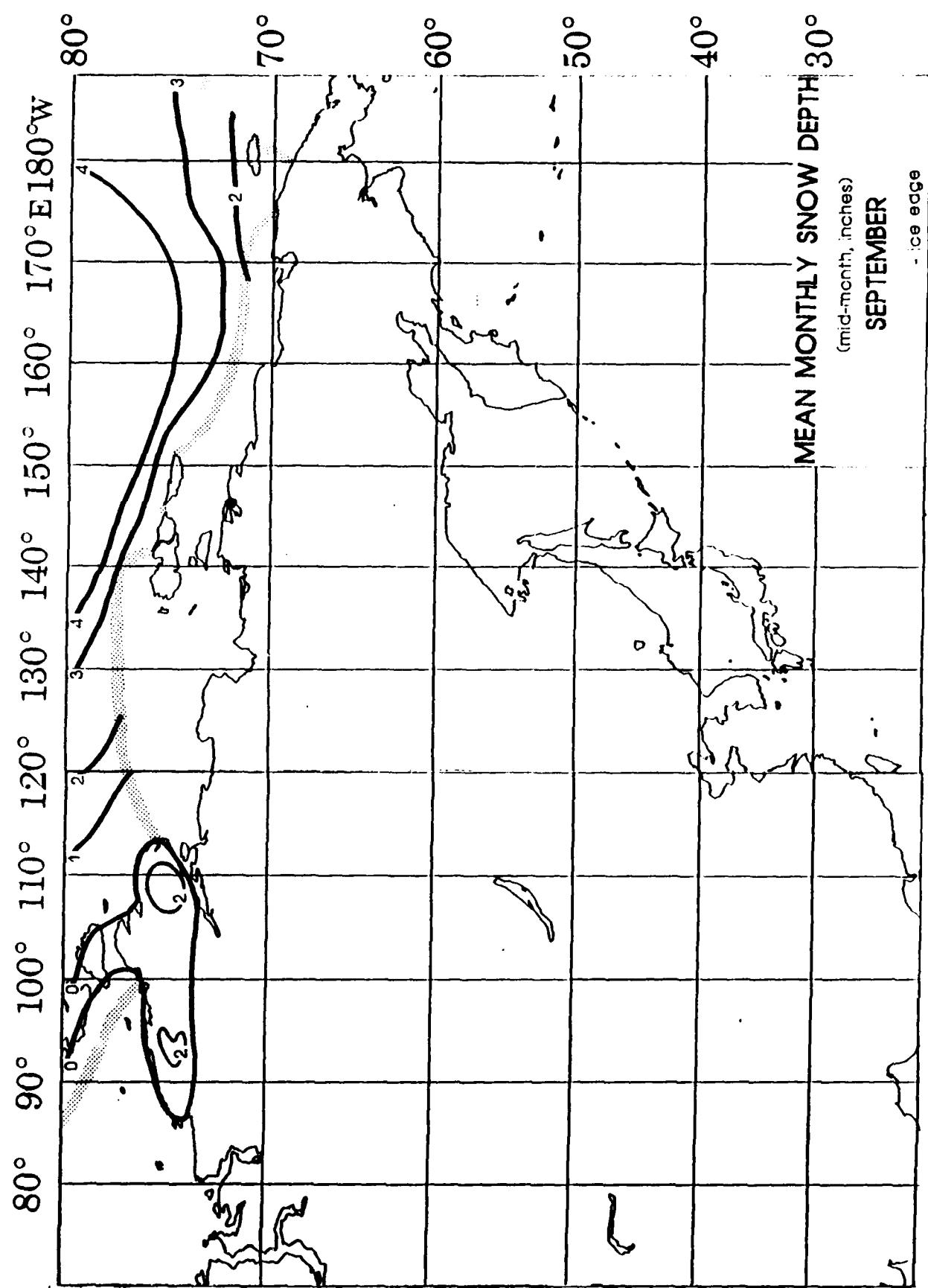


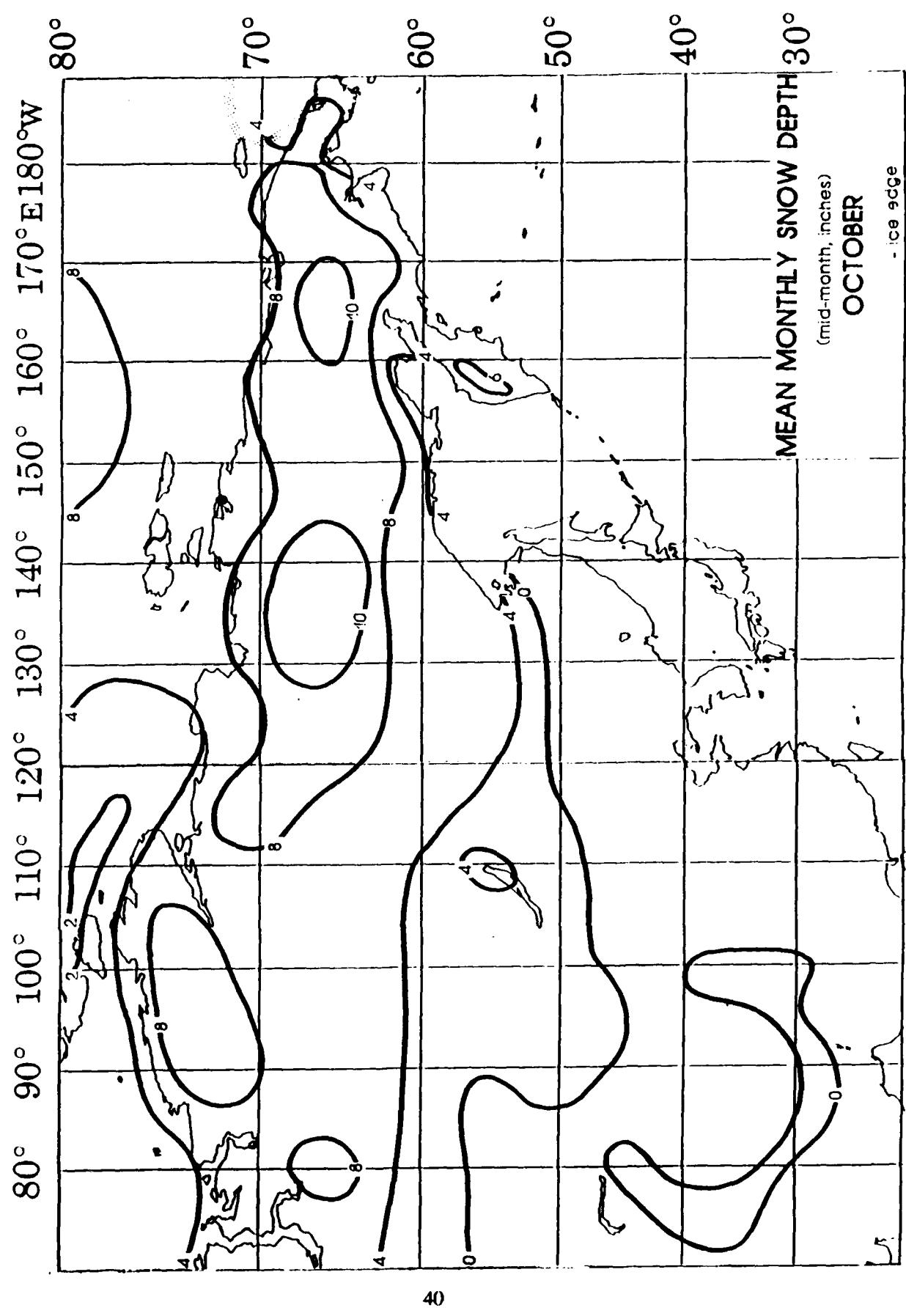


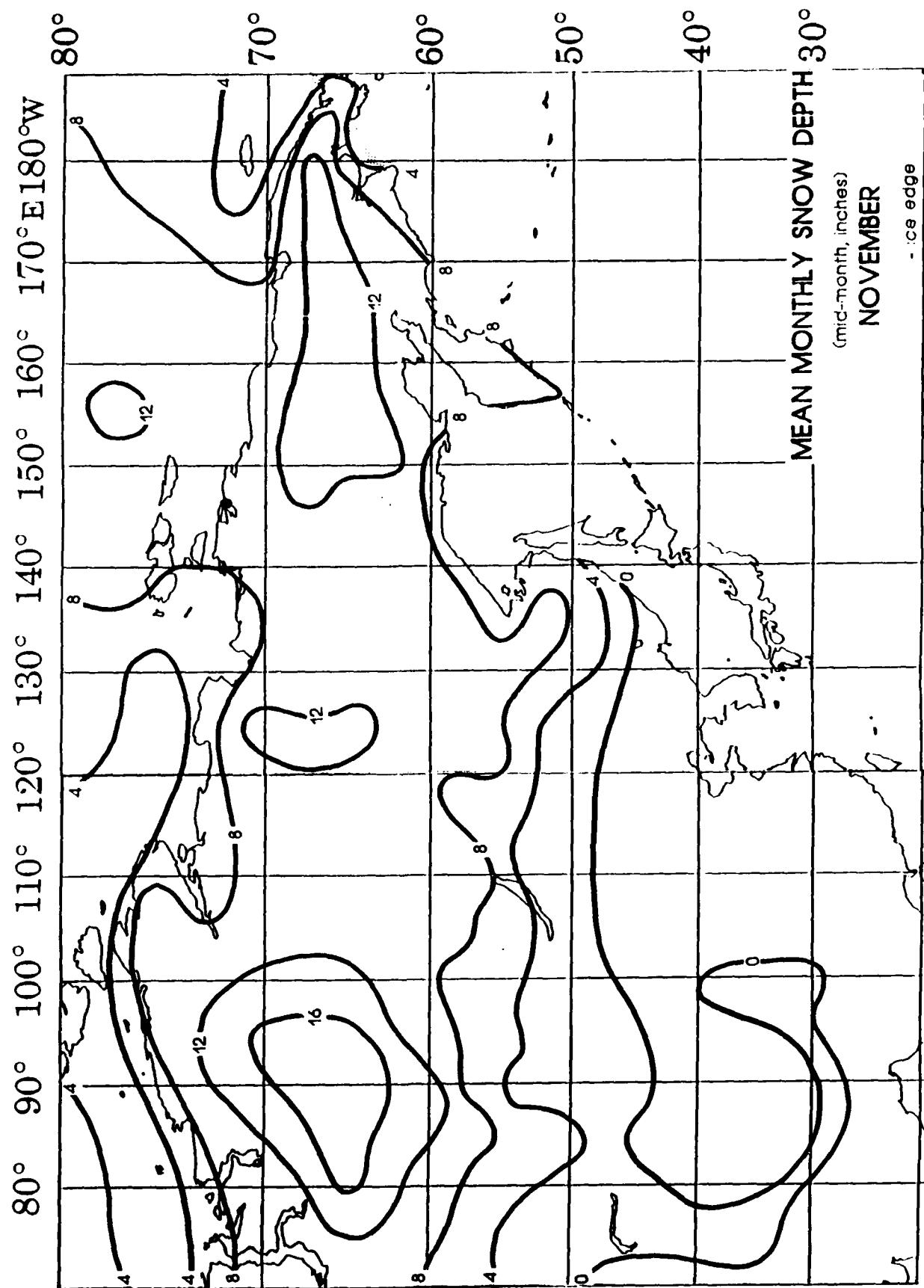


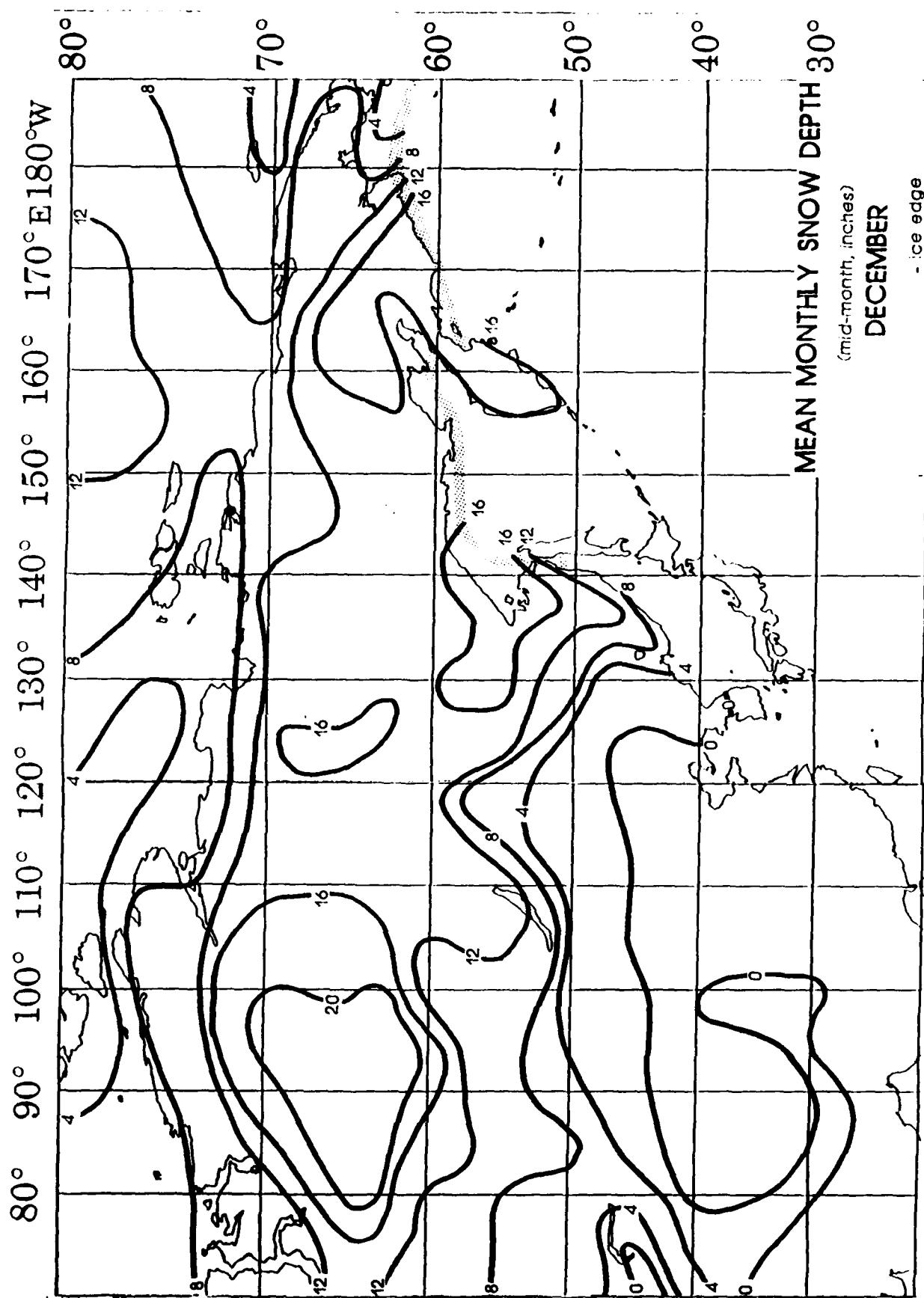


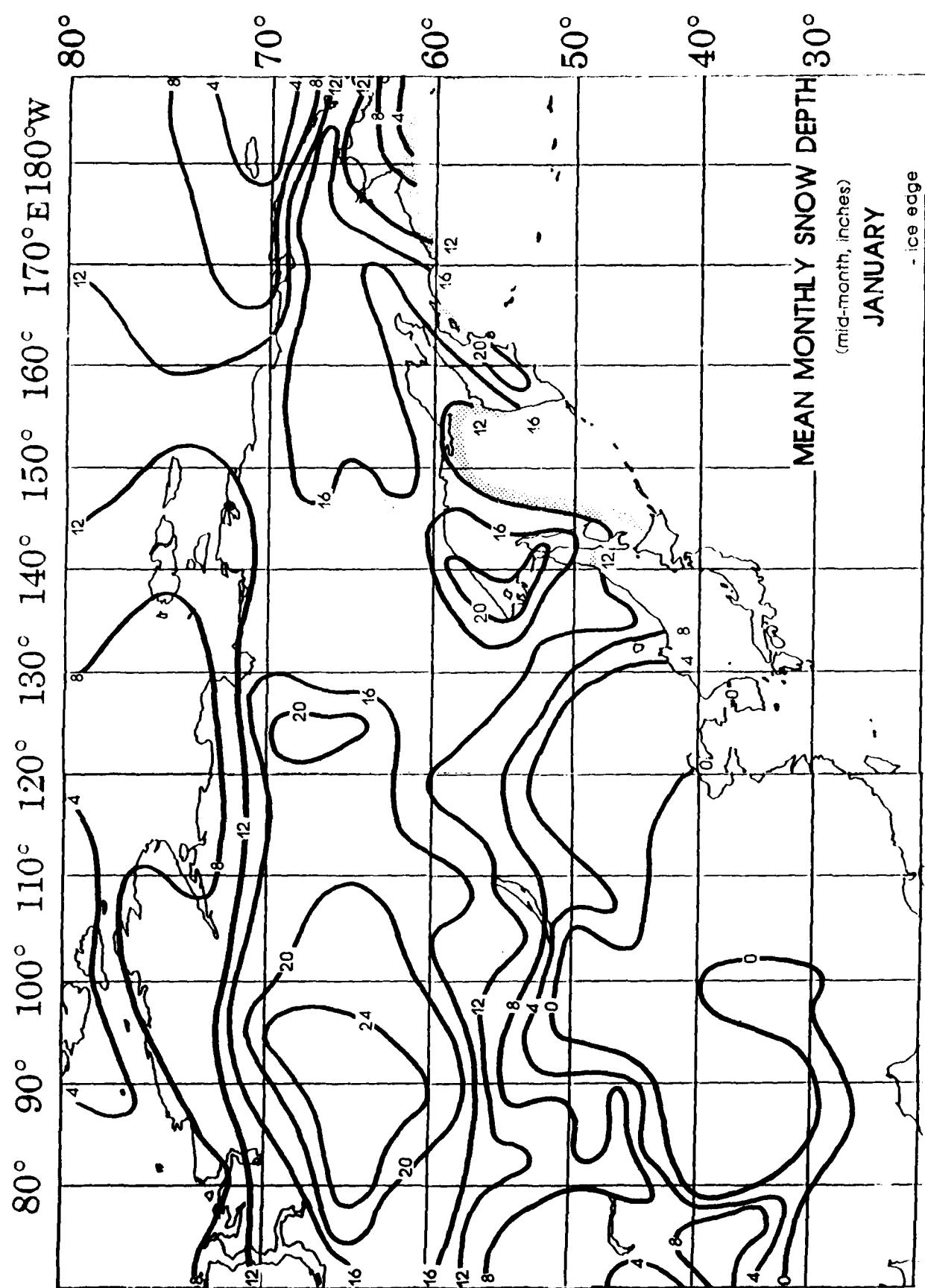


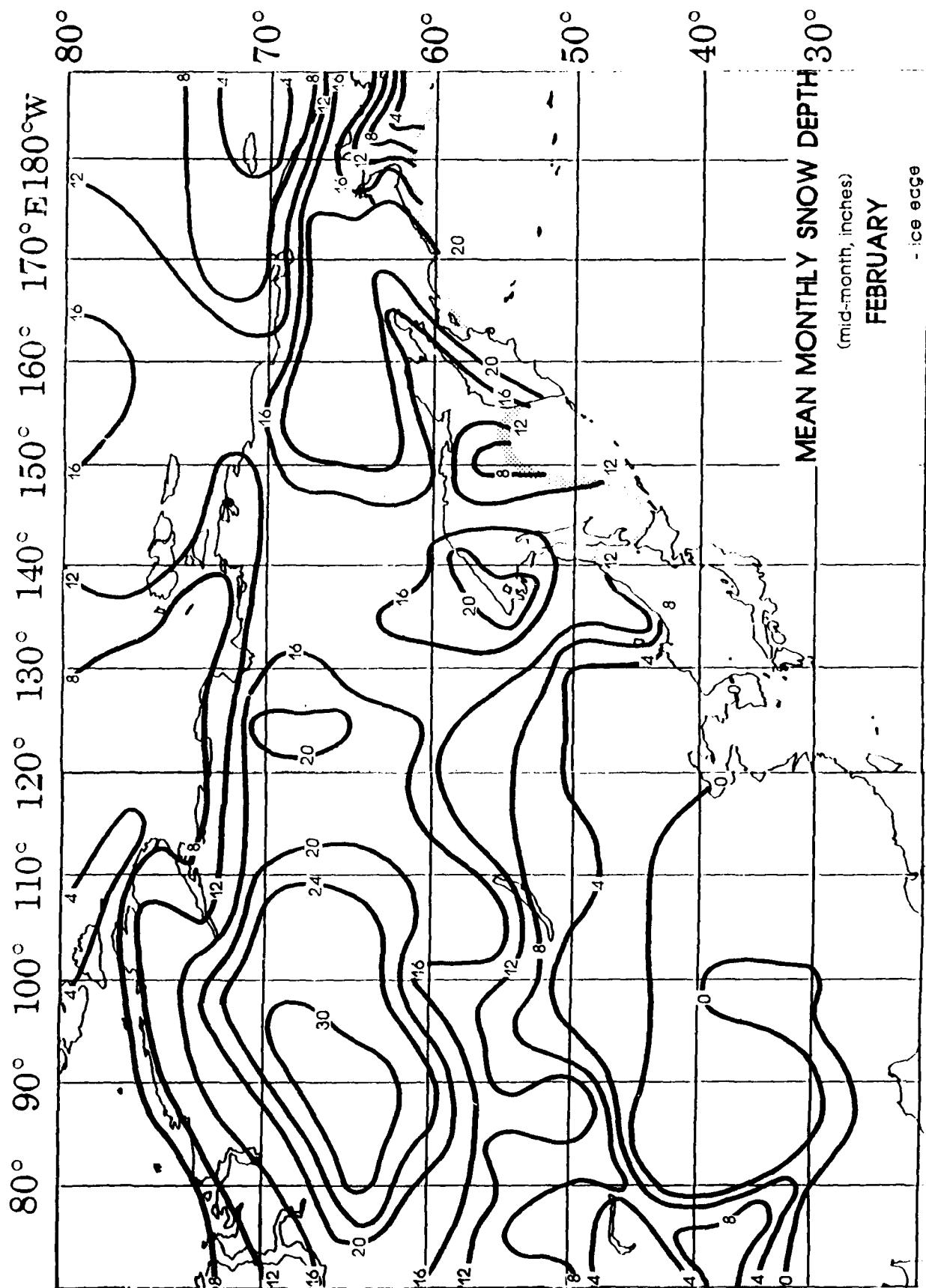


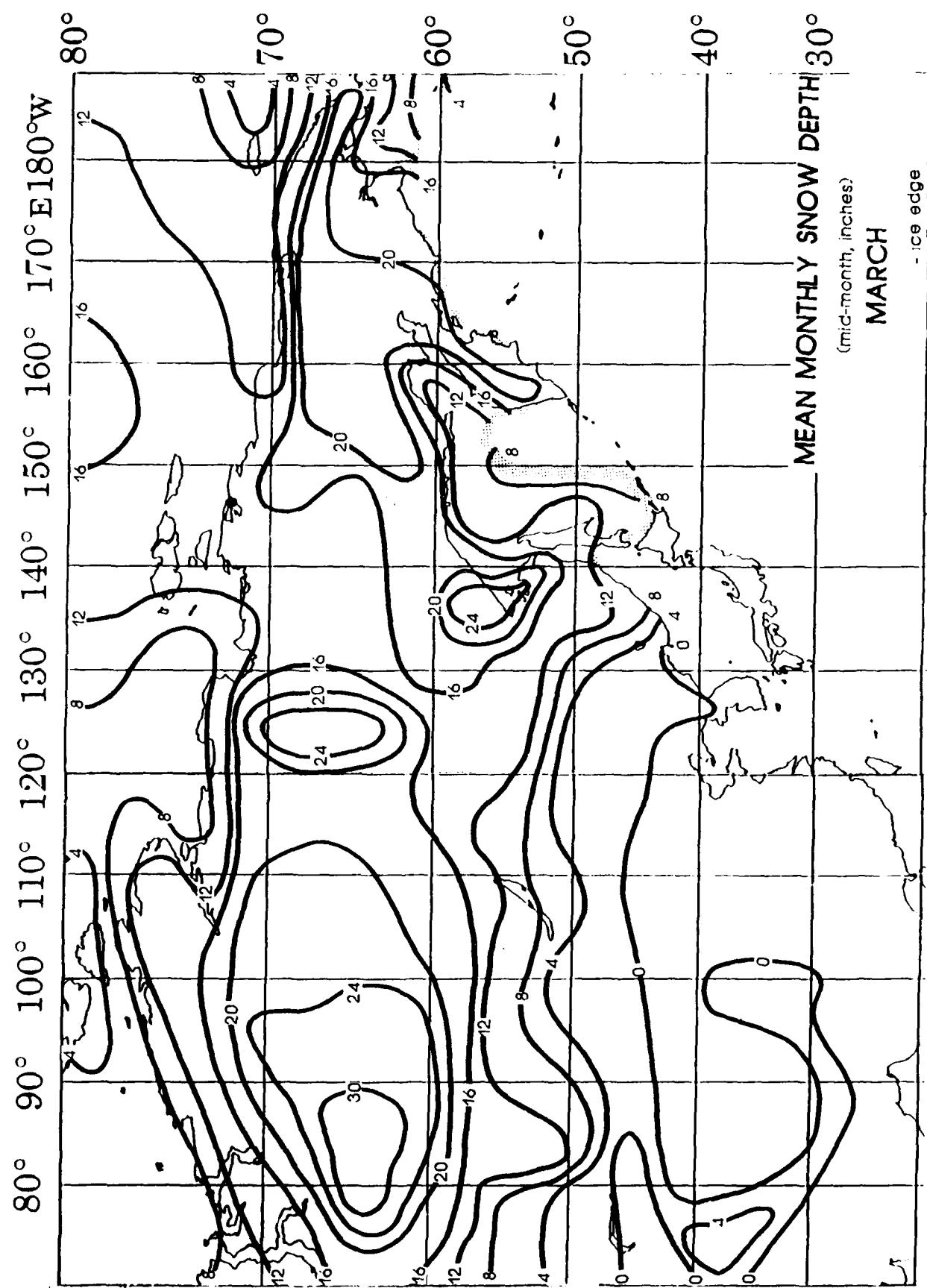


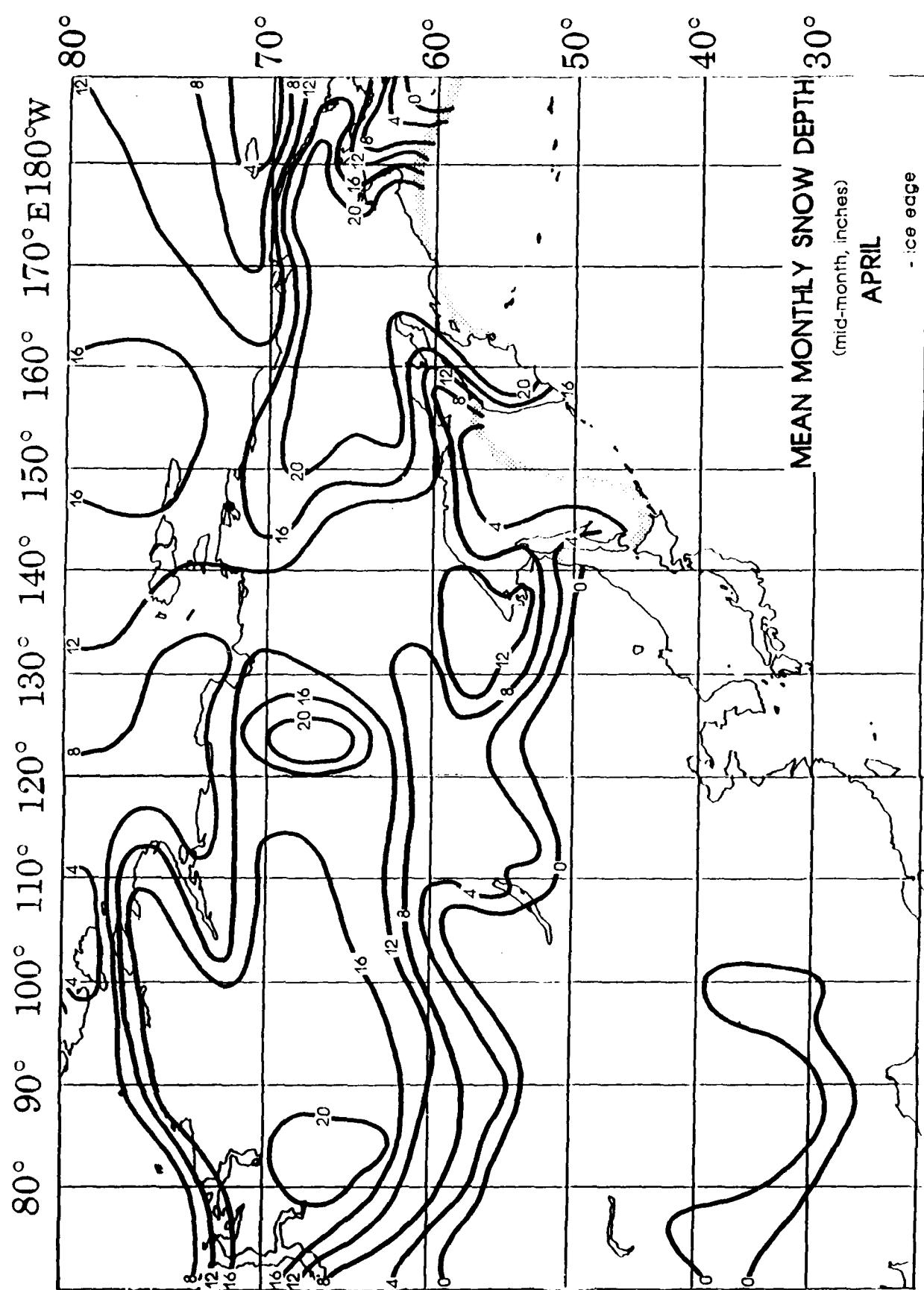


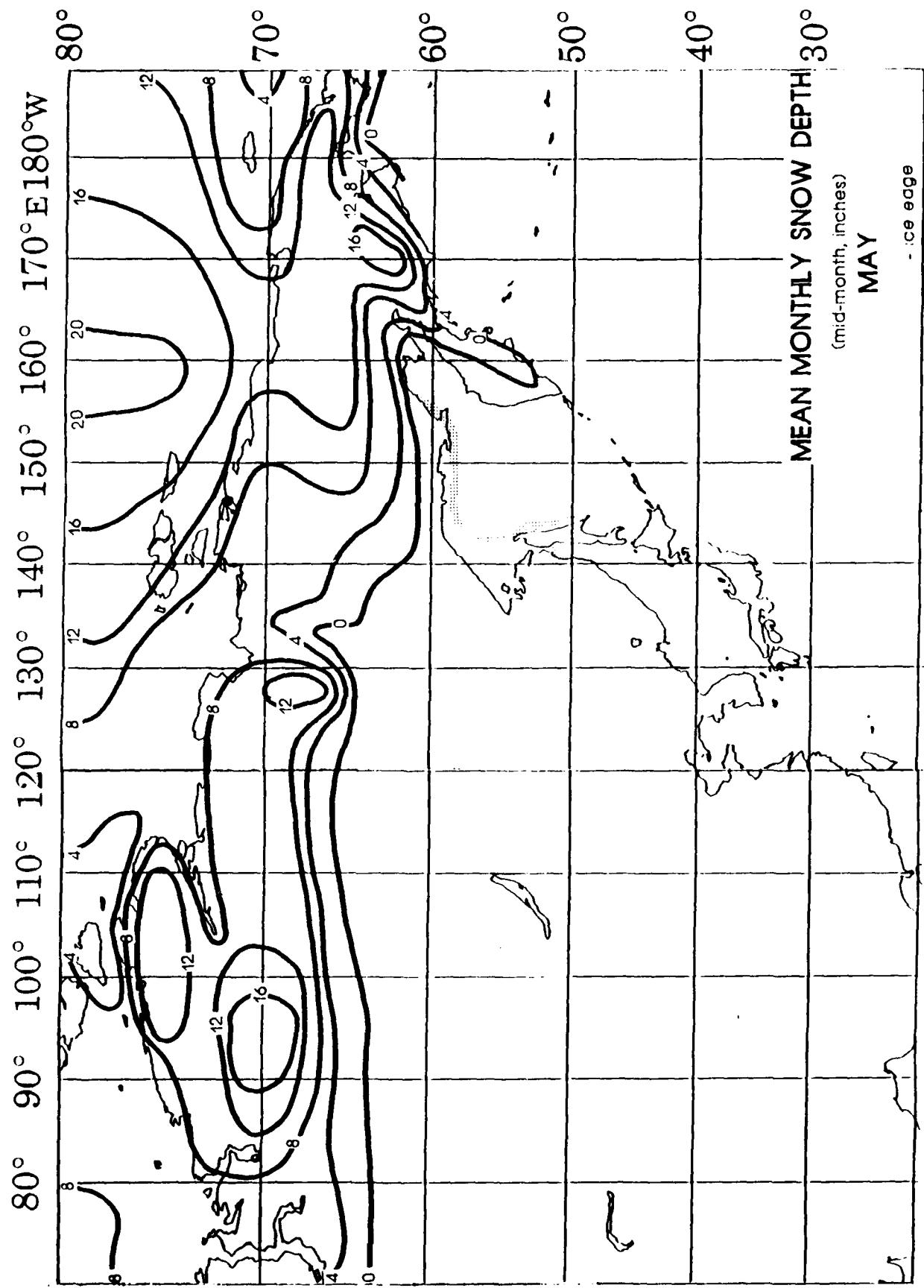


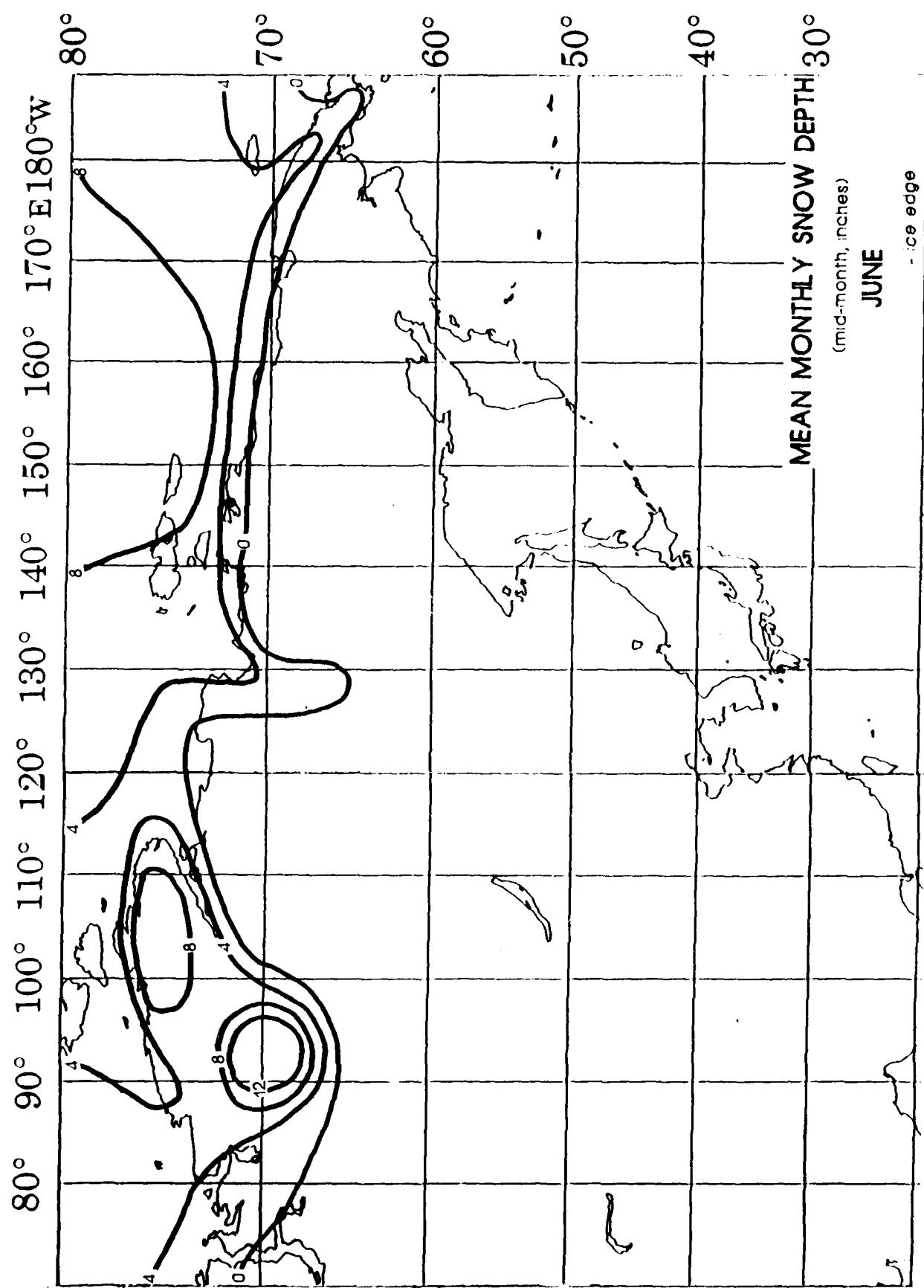












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